The Science & Technology Resources of Japan:

A Comparison with the United States

An SRS Special Report

Division of Science Resources Studies – Directorate for Social, Behavioral, and Economic Sciences

NSF 97-324

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Foreword

In its 1988, report, *The Science and Technology Resources of Japan: A Comparison with the United States*, the Division of Science Resources Studies (SRS) provides some key trends on science investments and outcomes. Science and technology decision-makers and the research communities in Japan and the United States found the report useful. This report updates that report, providing data on the many changes in the funding of science and in graduate education in the United States as well as Japan.

The information presented here complements that in a number of other sources. They include special reports on Japanese science presented in several issues of *Science* from the American Association for the Advancement of Science (AAAS), the reports of NSF's Tokyo office over the last several years, and the international coverage in the *Science and Engineering Indicators* report of National Science Board.

Jeanne E. Griffith, Director
Division of Science Resources Studies
Directorate for Social, Behavioral,
and Economic Sciences

November, 1997

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My colleagues within the National Science Foundation (NSF), Division of Science Resources Studies (SRS), particularly Lawrence Rausch, provided me with some of the data on output indicators. Jennifer S. Bond, Program Director of the Science and Engineering Indicators Program, enthusiastically gave guidance and encouragement during my fellowship in Japan as well as in the preparation of this report within the SRS Division. Mary J. Golladay, Program Director of the Human Resources Statistics Program, Carlos E. Kruytbosch, then Program Director of the Science and Engineering Personnel Program, and Ann Lanier, Senior Analyst in SRS, reviewed the draft and provided helpful suggestions. John Jankowski, Program Director of the Research and Development Statistics Program, also carefully read the draft and suggested changes in reporting and footnotes in several R&D data series in order to yield greater consistency with other SRS reports. Anne Houghton, Julia Harriston, and Tanya Gore of SRS provided copyediting, processing, and final composition of this report. Laurie Leonard, Robert H. Brown, Heather Gowallis, Jerrilyn Heller, and Paulette Shaw of Global Associates, Ltd., provided proofreading, table and chart formatting, and composition services. Several peer reviewers provided useful comments and suggestions, including Shinichi Yamamoto, Philip Altbach, Maria Papadakis, and Ryo Hirasawa. Larry H. Weber, of NSF's Division of International Programs (who recently returned from a 5-year assignment as Director of the NSF Tokyo office), refined my understanding of recent changes in Japan in both science policy and programs.

Dr. Jean M. Johnson, Senior Analyst, Science
and Engineering Indicators Program

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Introduction

While the United States invests more than Japan in research and development (R&D), Japan's R&D investments relative to the size of its economy are slightly larger than those of the United States. In 1994, for example, Japan invested 2.6 percent of its gross domestic product (GDP) in R&D compared with 2.5 percent by the United States. With a GDP that was only 39 percent of that of the United States ($2.1 trillion versus $5.3 trillion in constant dollar terms) in 1994, Japan's overall R&D expenditures were 41 percent of those of the United States—$54 billion versus $133 billion.[1] Japan's proportion of GDP invested in overall R&D began to surpass that of the United States in 1989 and has continued for several years. (From 1975–88, the United States invested a relatively larger amount in R&D than did Japan.) (See table A-1.)

Japan's effort in basic research, however, has been somewhat lower than that of the United States, but this area is currently receiving special attention in Japan. From 1976–88, Japanese spending on basic research, relative to the size of its economy, generally remained at about 80 percent of U.S. levels (Papadakis and Jankowski, 1991) and was conducted mainly in industrial laboratories. From 1980–92, average annual rates of growth in investments in basic science in Japan outpaced GDP growth rates by 5.9 percent versus 4.2 percent, respectively. By 1992, Japan's basic research expenditures reached about 84 percent of those of the United States, representing about 0.38 percent of GDP. In that same year, U.S. basic research expenditures represented 0.45 percent of GDP. While Japan has traditionally invested a smaller percentage of its overall R&D in basic research compared with the United States (table A-6), since 1992, Japan has adopted the goal of improving its basic research and innovation capacity—particularly in universities—through increasing government support of R&D.

To understand the context of this recent shift to focus on basic science, the development of Japan's science and technology (S&T) policy can be briefly summarized in three main phases: the well-known catch-up phase following World War II; the initiatives for innovative technologies in the 1970s following the oil crisis; and the new funding programs of the 1990s to change the culture of science in Japan and promote breakthrough research.

Following World War II, Japan rebuilt its economy by consciously investing in quality engineering to improve on imported technologies. From 1945–72, Japan successfully carried out a technology policy of importing Western technology and investing large amounts of R&D funding on adaptive technology (Tamura and Peck, 1983). Initially significant in this post-war development period were the policies of the Natural Resources Section[2] and the Scientific and Technical Divisions of the Occupation Forces. The latter played a key role in rehabilitating Japan's capacity for scientific inquiry (Yoshikawa and Kauffman, 1994). The process of catching up after the war included the selection of technologies developed overseas, long-term investment in adaptive research, and marketing of improved products. The Japanese government assisted in this catch-up phase, most notably by adopting trade policies that protected Japanese firms from competition and by restricting foreign investment in Japan (Odagiri and Goto, 1993, and Goto, 1995).

The serious environmental problems of the 1960s and the energy crisis of the early 1970s motivated Japan to advance to a second phase of S&T policy: building its capacity for indigenous and innovative technology for sustainable development. The Japanese S&T White Paper in 1973 began urging a restructuring of research toward this end. This S&T document provided a vision of a new focus for Japanese R&D—that of performing basic research related to the goals of developing environmentally sound technologies for the nation (Science and Technology Agency (STA), 1973). The ensuing 20 years saw a gradual evolution of science structures and the introduction of new programs for the support of innovative research, including a competitive grants-in-aid program in the universities, new mechanisms for funding young scientists from industry and universities on fixed-term appointments, and a redirection of national laboratories toward long-term basic research.

[1] All dollar amounts in this report are in 1987 constant dollars using purchasing power parity (PPP) conversions. PPP conversion rates for Japanese yen are given in table A-1. PPPs are used to convert a country's national currency expenditures to a common currency unit that allows *real* international quantity comparisons to be made. PPPs are based on "market basket" pricing exercises. See Methodology and Notes on Data Series for details on why PPP conversions are preferable to market exchange rates.

[2] The Natural Resources Section of the Occupation forces reported on Japan's natural resources, as well as resource requirements for Japan to recover and advance to the highest economic level (Yoshikawa and Kauffman, 1994).

The third phase of S&T policy began in the 1990s with the growing awareness among Japanese S&T decision makers that continuing their formerly successful strategy of emphasizing research to adapt imported technology would not provide the capabilities required in new and rapidly developing technologies, such as biotechnology, gene therapy, and software for computer networks (Ichikawa, 1996). Competition from Asian emerging economies further increased Japan's awareness of the need for ever more advanced industries based on fundamental science.

In 1992, therefore, Japan's Cabinet called for a doubling of the government's R&D budget as soon as possible, and expanded funding of new programs and mechanisms for innovation research. The S&T policy document[3] of that year recommended a major renewal of facilities and equipment in the universities and national research institutes and an expansion of competitive research grants. Subsequently, in 1995, the Science Council of Japan created the legislative support to increase the science budget through the Science and Technology Basic Law. The S&T Plan of 1996 suggests that the government of Japan invest 17 trillion yen in R&D from 1996–2000, equivalent to $74 billion in 1987 constant dollars. This would represent a sizable increase (35 percent) over the amount spent in the previous five years—approximately $51 billion in constant dollars from 1991–95 (table A-4). To this end, the Japanese government increased its R&D budget in 1996 by 12.5 percent and the Cabinet-approved 1997 R&D budget has an additional 6.8-percent increase.[4]

Despite Japan's economic recession, the Science Council managed to generate unanimous support in the Diet to use the sale of construction bonds to increase science funding.[5] The notion of restructuring the economy through knowledge and education is widely held throughout the Japanese culture (Rohlen, 1992). Those Japanese over age 50 have lived through the reconstruction of Japan from devastation to become a leading world power. Those Japanese under age 50 are told repeatedly that in a country with few natural resources, education and S&T must be key national resources for prosperity.

[3] Basic Policy for Science and Technology (approved by the Cabinet, April 1992) based on the 18th Recommendation of the Council for Science and Technology (January 24, 1992), a report on the Comprehensive and Basic S&T Policy: Toward the New Century.

[4] Still pending Diet approval.

[5] The use of construction bonds required Ministry of Finance approval.

The passage of this new Science and Technology Basic Law indicates that improving Japan's S&T capacity for innovative research is a national priority. Mobilizing strategic basic research is deemed essential for recovery from recession and for the long-term sustainable development of Japan. In the summer of 1996, the Science and Technology Basic Plan required national science agencies, as well as local governments, to submit 5-year plans on how they will accomplish this transition to a higher standard of S&T in Japan.

Although increasing the government science budget received unanimous support in the Diet, the tactic used to generate new research funding through the issuance of construction bonds remains controversial. The Science Council and the science community have argued that this investment in innovative research will yield breakthroughs for future industries, increasing the tax base and allowing repayment to the public for all the bonds floated. Japan's Ministry of Finance and some Diet members are concerned, on the other hand, about whether or not the bonds will be paid back in a timely manner (Ikeda, 1996).

A deeper concern is whether or not this new money will actually improve the quality of basic research and innovation. Research scientists and science policy decision makers alike cite the need to change the culture of science in Japan to provide a more competitive research environment and to increase human resources for science. (Kitazawa, 1996). Appropriately, the Science and Technology Basic Plan (July 1996) and the White Paper on Science and Technology (1996) focus on steps to be taken from 1996–2000 to improve the climate for basic research in Japan (STA, 1996).

This report provides comparisons of U.S. and Japanese science resources and some initial evidence that Japan is expanding the human and financial resources for science, while improving the environment for basic research. The data cover S&T trends in overall R&D from 1975–94 as well as more recent changes in government and university research in Japan. It also covers research trends in private industries and the training of personnel within Japanese companies and in American universities. The report concludes with the implications of these changes to the U.S. and international research community and the need for further research.

Highlights

National Research and Development (R&D) Patterns

- In the last two decades, both the United States and Japan have had strong growth in R&D, followed by slight annual declines from 1991–94.

- Japan's overall R&D investments are slightly larger than those of the United States. In 1994, Japan invested 2.6 percent of its gross domestic product (GDP) in R&D whereas the United States invested only 2.5 percent of its GDP. Japan's higher investment in overall R&D compared with that of the United States (relative to the size of its economy) began in 1989 and has continued for several years.

- In non-defense R&D Japan significantly outspends the United States relative to the size of its GDP. Japan has invested between 2.5 percent and 2.8 percent of its GDP in civilian research for the past 10 years. The United States has invested approximately 2.0 percent of its GDP in civilian R&D over the period from 1975–94. Defense R&D in the United States declined to 20 percent of overall R&D by 1994, from a high of 32 percent in 1987. In contrast, Japanese defense research is only 1 percent of overall R&D.

- In Japan, industry has historically funded a larger share of R&D than the government sector. In 1990, industrially funded research reached 78 percent of total R&D in Japan. By 1994, however, government support of total R&D reached almost 20 percent while industry support declined to 73 percent.

- The government of the United States has been a more significant source of support for R&D than that of Japan if defense R&D is included. U.S. government-sponsored research grew rapidly in the 1980s, peaked in 1987, and has since declined, following worldwide reductions in defense R&D since the late 1980s. U.S. Government support of overall R&D fell from 45.8 percent in 1985 to 35.0 percent in 1995.

Science and Engineering Personnel

- Japan has more engineers as a proportion of its overall labor force than the United States. In fact, relative to the size of its labor force, Japan has more engineers than any leading industrial nation except Sweden (NSF,1996c). This engineering concentration stems from the large number of engineering degrees earned at the undergraduate level in Japan (See section on Higher Education: undergraduate level).

- The stock of scientists and engineers relative to the labor force is sharply increasing in Japan but only moderately so (for scientists) in the United States. The Japanese stock of scientists and engineers grew 8.0 percent annually from 1985–90. In contrast, in the United States the stock of engineers remained stable between 1986 and 1991, at 146 per 10,000 of the labor force, while the stock of scientists moderately increased from 109 per 10,000 of the labor force in 1986 to 135 per 10,000 in 1991.

- Japan has more scientists and engineers engaged in R&D relative to its labor force than the United States. In 1993, Japan had 80 research scientists and engineers per 10,000 of the labor force, while in that same year U.S. researchers numbered 74 per 10,000 of the labor force.

Government R&D

- In the 1990s, the government is the dynamic growth sector of R&D in Japan. After a decade of stagnant funding throughout the 1980s, Japanese government support of R&D has increased 5.7 percent annually in real terms in the 1990s, from $9 billion in 1991 to $13 billion in the 1997 science budget authorization (in inflation-adjusted PPP dollars).[6] The Japanese government increased its share of overall R&D support from 16 percent in 1990 to 20 percent in 1994.

[6] The 1997 government science budget received Cabinet approval and awaits Diet approval.

- Japan's Cabinet Decision of 1992 called for doubling the government R&D budget as soon as possible. The Basic Plan for S&T of 1996 suggests that the government allocate 117 trillion yen (equivalent to approximately $74 billion in constant dollar terms) to R&D from 1996 to 2000, a 35-percent increase over the previous 5 years of government funding of R&D. In contrast, the 10-year trend for government-sponsored research in the United States has been a declining real budget. At the peak of public funding for research in 1987, the U.S. Government invested $57.9 billion. In preliminary data for 1997, U.S. Government investment decreased to $47 billion.

- Government-funded civilian R&D as a percent of GDP declined both in Japan and in the United States throughout the 1980s, followed by an increase in support of civilian R&D in the 1990s. However, from 1990–96, Japan had a higher annual rate of growth in its government budget for civilian research (5.9 percent) than the United States (1.5 percent). By 1996, Japanese government civilian R&D rose to 0.54 percent of GDP; that of the United States represented 0.40 percent of GDP.

- The Japanese government spends the largest portion of its R&D budget—an estimated 51 percent—on the general objective of "advancement of knowledge," which includes general university research funds (not to be equated with basic research). The second most important objective of Government R&D funding in Japan is energy research—approximately 21 percent. The U.S. Government funds the majority of its R&D budget on defense—55.3 percent in 1994—followed by health research at approximately 17 percent.

Industrial R&D

- Although government R&D budgets have recently increased, industrial laboratories still conduct the vast majority of Japan's research, funding nearly 75 percent of the total resources for R&D and employing nearly 70 percent of the research scientists and engineers.

- In both the United States and Japan, industrially funded R&D increased rapidly from 1975 to the peak year in 1991, followed by stagnant or slightly declining industrial R&D investments each year until 1994. This downward trend may have been reversed in the United States in 1995. Japanese industry investment in R&D rose from $11.4 billion in 1975 to $44 billion in 1991, representing an 8.9-percent average annual growth rate. In the peak year of industrial support of R&D, 1991, private industry accounted for 78 percent of overall R&D in Japan. Industrially supported research in Japan declined an average of 3.1 percent annually from 1991–94.

- As a percentage of gross domestic product (GDP), Japan's industrial R&D doubled from 1975–90, and declined slightly in the 1990's. In 1994, the ratio of overall Japanese industrial R&D to GDP—1.9 percent—was comparable to the U.S. proportion of 1.8 percent. However, Japanese industrial R&D is almost entirely (98 percent) financed by companies themselves. This Japanese company-funded R&D as a percentage of GDP has surpassed the U.S. ratio of company-funded R&D to GDP every year since 1975. In 1994, the ratio of company-funded R&D represented 1.9 percent of GDP for Japan and 1.5 percent for the United States.

- Japanese industrial R&D is enhancing its science base, and shifting among areas of concentration. For example, the proportion of R&D in the science-based, newer industries of drugs and medicines, computers, and electrical machinery has increased, and that in automotive industries, chemicals, and the basic metals industry of iron and steel has decreased.

- In both the United States and Japan, the number of industrial scientists and engineers increased at an average annual rate of growth greater than 5 percent throughout the 1980s. However, Japanese industry continued to increase employment of R&D scientists and engineers despite the economic recession in the 1990s. In the United States, industry decreased the number of scientists and engineers employed in R&D by about 25,000 from 1992–94.

- Japan has more R&D scientists and engineers (RSEs) per 10,000 employees in manufacturing companies than the United States. In 1993, Japan employed 622 RSEs per 10,000 employees in manufacturing companies, compared with 520 in the United States that same year. The higher employment of RSEs in manufacturing companies in Japan has existed since 1985.

Higher Education

- With a population that is less than one-half that of the United States, Japan produced more than 91,000 engineering degrees in 1994 compared with approximately 63,000 in the United States. Some of this disparity stems from the difference in taxonomies used in higher education: faculties of computer science and solid-state physics are included in engineering in Japanese universities. Albeit with a broader definition of engineering, Japanese undergraduate students earn 20 percent of their degrees in engineering fields,[7] far greater than the 5 percent of students in the United States who earn their undergraduate degree in engineering. Relative to the size of its population, Japan has three times more engineers earning university degrees and entering the labor force than the United States.

- Few students in Japan earn degrees in natural science fields at the undergraduate level. Only 3.5 percent of the undergraduate degrees in Japan are earned in natural sciences (physical, environmental, and biological sciences), and 2.9 percent are earned in agricultural sciences. In the United States, 9.3 percent of all undergraduate degrees are earned in the natural sciences, and 1.1 percent are earned in agricultural sciences.

- Graduate S&E programs, traditionally small in Japan, have begun to expand. Graduate enrollment in S&E fields increased from 31,000 in 1975 to more than 91,000 in 1994. Even with the recent expansion, however, Japanese graduate enrollment in all S&E fields was still small compared with the 433,000 graduate S&E students enrolled in U.S. universities. Particularly small are Japanese graduate programs in the natural sciences (12,000 graduate students in Japan versus 120,000 in the United States). Relative to its size, Japan's graduate enrollment in natural sciences is about one-quarter those of the United States. In contrast, engineering graduate programs in Japan have comparable enrollment to those in the United States (relative to the size of its population).

- Until recently, most doctorates in natural sciences and engineering in Japan were earned by industrial researchers after many years of research within Japanese companies. With the expansion of university-based doctoral programs, however, the proportion of these degrees earned is decreasing. By 1994, more doctoral engineering degrees were earned for research within university laboratories (53 percent) than for those within industrial research laboratories (47 percent).

Foreign Students

- The majority of foreign students in Japan are at the undergraduate level. In 1994, only 17,800 of the 50,000 foreign students in Japan were studying at the graduate level. By contrast, almost one-half of the 425,000 foreign students in the United States in that same year were studying at the graduate level. Of approximately 191,800 students who came to the United States for graduate studies in 1994, almost one-half were pursuing degrees in the natural science and engineering fields. Likewise, more than one-half of the foreign graduate students in Japan were in S&E fields.

- In 1992, foreign students earned 37 percent of engineering doctoral degrees within Japanese universities and 25 percent of natural science doctoral degrees. By contrast, in U.S. universities foreign students earned slightly more than 50 percent of the engineering doctoral degrees and one-third of the natural science doctoral degrees in 1993.

Academic R&D

- The decade-long trend, observed from 1980–91, to a diminishing role for academic performers in total Japanese research and development ended in 1992. In that period, academic performance decreased from a 17-percent share to a 12-percent share of

[7] Japan's percentage is similar to the proportion of engineering degrees in Singapore, Korea, and Taiwan. Only China has a considerably higher concentration on engineering: 40 percent of Chinese undergraduates study engineering (NSF, 1993).

total Japanese R&D performance. As a result of strong support provided by the government's 1993 and 1994 budgets, Japan's academic performance rose to a 14-percent share of total Japanese R&D.

- In the 1990s, Japan's Ministry for Education, Science, Sports and Culture (Monbusho) has increased university research funding through competitive grants-in-aid. In addition, after 1995 government agencies other than Monbusho have been contributing directly to academic science. Monbusho has recently written legislation to allow direct funding of university researchers by other science agencies: the Science and Technology Agency (STA) and the Ministry of International Trade and Industy (MITI). The majority of university research funding, however, still comes from Monbusho's formula funding of university chairs.

- By 1996, about 6,000 Japanese graduate students and postdoctorates had some government funds. The target is to fund about 10,000 government fellowships by the year 2000. The ability of faculty and national laboratories to hire postdoctorate researchers and research assistants contributes to the expansion of the universities' capacity for conducting basic research.

- The Japanese government, under Monbusho and STA funding, is supporting cutting-edge facilities and is a contributing member of the European Center for Nuclear Research (known by its French initials, CERN) for international cost-sharing. Monbusho's support of new world class facilities and "big science" will allow the expansion of basic science in the fields of astronomy, high energy physics, space science, environmental earth science, and bioscience.

Outputs and Impacts

- Japan's goal of increasing its international cooperative research, as stated in S&T White Papers since the mid-1980s, has resulted in increased international coauthorship in its scientific literature. During the 1988–93 period, almost 11 percent of Japan's scientific articles in this set of journals were internationally coauthored, up from 7 percent in the previous period of 1981–87. While U.S. scientists are still the main collaborators on internationally coauthored articles with Japanese scientists (43 percent), an increasing percentage of Japan's internationally coauthored articles are based on collaborations with scientists from European (34 percent) and Pacific Rim (14 percent) countries, particularly China.

- Japan's strong growth in industrial R&D throughout the 1980s corresponds with similar strong increases in the number of patents during the same period. From 1980–90, the number of U.S. patents granted to Japanese scientists and engineers increased at an average annual rate of 10.6 percent—from 7,000 in 1980 to 19,524 in 1990. Despite a recent slowing in patent growth rate, Japanese inventors still received about 23 percent of all U.S. patents in 1993 and represented almost half of all foreign patents granted in the United States, indicating a strong level of inventiveness.

- While Japan has traditionally been a net importer of technological know-how, data for 1990 show Japanese manufacturing industries' trade in technological know-how nearly in balance in 1990. By 1993, Japanese companies received more royalties and fees than they paid for technological know-how in several industry fields, including industrial chemicals, ceramics, iron and steel, and fabricated metals. Additionally, in motor vehicles, the ratio of receipts to payments was 14 to 1, reflecting the spread of Japanese know-how in automobile manufacturing in Europe and Asia.

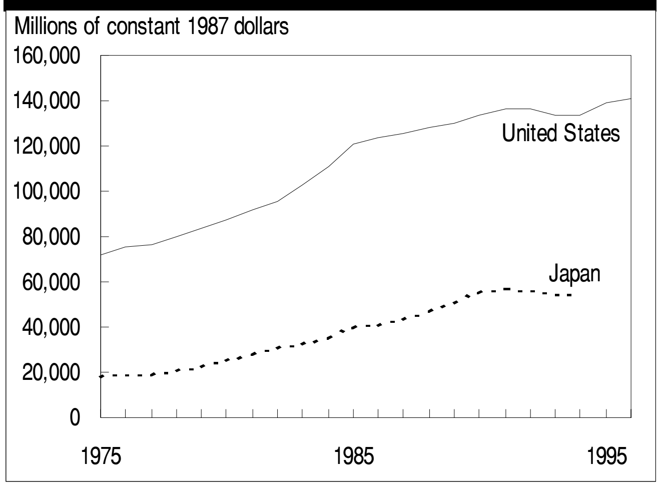
- In 1994 U.S.–Japan bilateral trade, Japan's export of advanced technology products reached more than $28 billion (exceeding imports from the United States by more than $14 billion), indicating that Japan is strong in the creation of such industrial output. The largest trade surpluses for Japan are from computers and telecommunications and electronics. The largest deficits for Japan from high technology trade with the United States result from aerospace and nuclear technology, and increasingly, from software.

Chapter 1. National R&D Patterns

Total R&D Expenditures

In the last two decades, both the United States and Japan have had strong growth in R&D, followed by slight annual declines from 1991–94. The similarity in this pattern of growth can be seen in figure 1. Japan's national expenditures on R&D grew at an average inflation-adjusted annual rate of more than 7 percent between 1975 and 1991, from $18 billion in 1975 to a peak spending of $57 billion in 1991.[8] During this period, U.S. real growth in R&D investments was strongest between 1975 and 1985 (5 percent annually). In the later half of the 1980s, growth in overall R&D in the United States shifted to a more modest rate of increase (2 percent annually), reaching $136 billion in 1991.

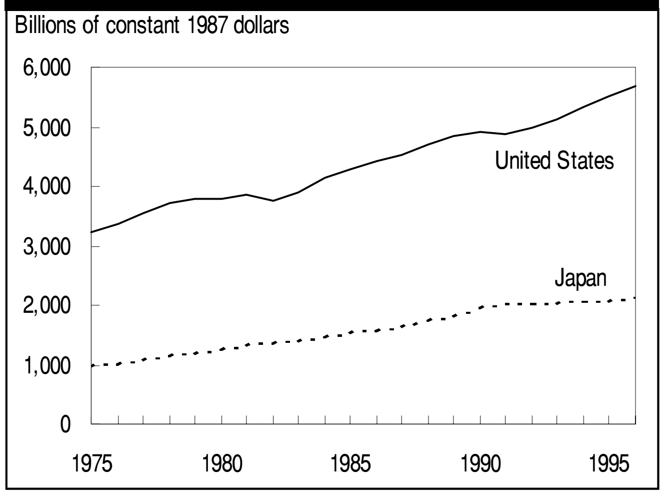
Figure 1. Total R&D expenditures



See appendix table A-1.

U.S. national R&D declined during 1993–94 in constant dollars, in part due to a decline in military R&D spending and in part from a slowdown in industrial R&D funding. In Japan, overall R&D declined in 1993 and 1994, not from cuts in military spending, but from the decrease in industrial R&D caused by Japan's economic recession. Figure 2 shows the accelerated growth in Japan's GDP (5 percent annually) from 1975–91, followed by a stagnant GDP from 1991–94. The sharp appreciation of the yen accelerated offshore production and concerns about "hollowing out" of Japanese industry and rising unemployment. These economic problems provided the political urgency for dramatic changes in Japanese S&T policy in 1995, to stimulate the economy in the short run and revitalize the economy in the long run.

Figure 2. Total GDP



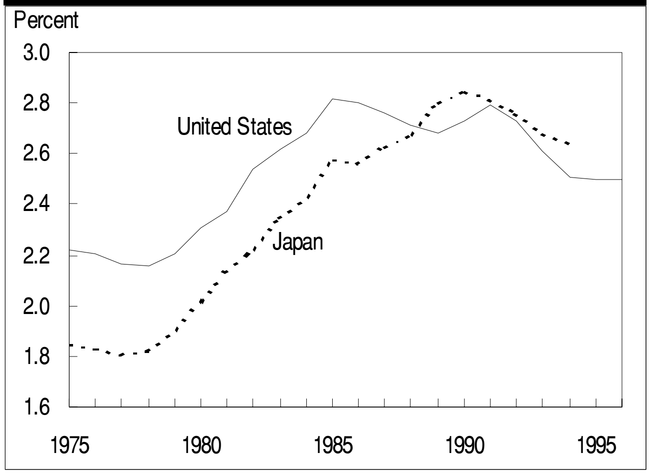
See appendix table A-2.

Even with recent industrial cutbacks in R&D, for the relative size of its economy, Japan invests an amount in R&D slightly larger than that of the United States. With a gross domestic product (GDP) that was approximately 39 percent of that of the United States ($2.1 billion versus $5.3 billion) in 1994 (figure 2), Japan's overall R&D expenditures were 41 percent of those of the United States ($54 billion versus $133 billion) (table A-1). Thus, Japan invests a slightly higher percentage of its GDP in R&D (2.6 percent versus 2.5 percent, respectively) (figure 3).

In non-defense R&D, Japan significantly outspends the United States relative to its GDP. Defense R&D in the United States declined to 20 percent of overall R&D by 1994, from a high of 32 percent in 1987. In contrast, Japanese defense research is only 1 percent of overall R&D. Japan has invested between 2.5 percent and 2.8 percent of its GDP in civilian

[8] Budget figures provided in this report are adjusted for inflation (constant 1987 dollars). The deflators for the Japanese yen are provided in appendix table 1, as well as the purchasing power parity conversions used for the dollar amounts. Japanese R&D data are taken from OECD's *Main Science and Technology Indicators*, and cover the period from 1975–94. This report uses the adjusted series for Japan. See methodology and technical notes on OECD Adjusted Data for Japan. Japan's government R&D budget authorizations for 1995–97 provide more recent evidence of the significant changes occurring in Japanese R&D.

Figure 3. Total R&D/GDP ratios

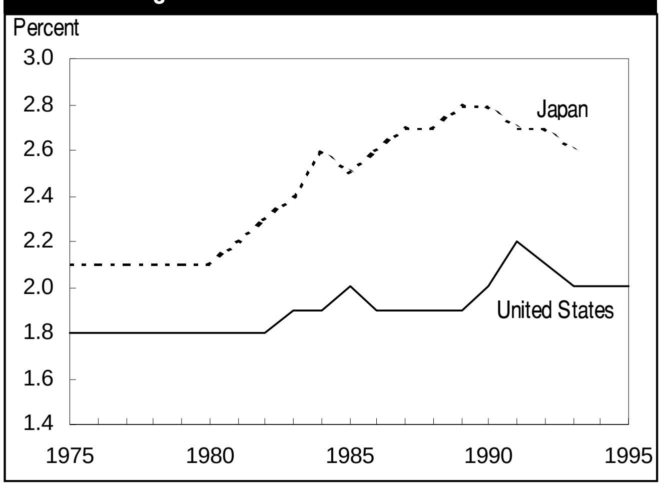


See appendix table A-2.

research for the past 10 years. (See figure 4.) The United States has invested approximately 2.0 percent of its GDP in civilian R&D over the period 1975–94.

Government investment in non-defense R&D as a percent of GDP shows an even wider gap between the United States and Japan. Estimated government nondefense R&D expenditures as a percent of GDP reached 0.51 percent in Japan in 1996. U.S. Government expenditures for nondefense research were 0.40 percent of GDP in 1995 (table A-3).

Figure 4. Nondefense R&D/GDP ratios

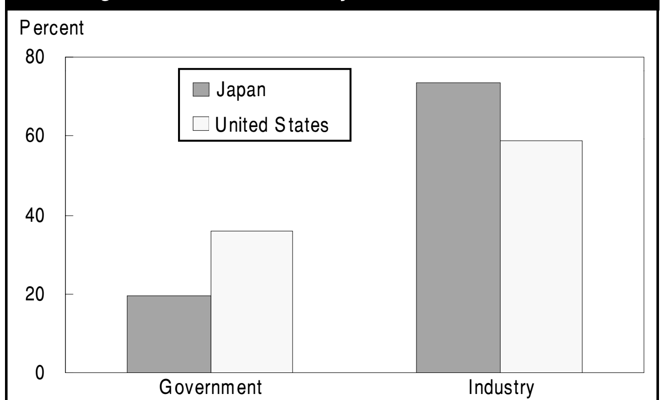


See appendix table A-3.

R&D Expenditures by Source and Performer

Industry historically has funded a larger share of R&D in Japan than has the government sector. However, the long-term trend in Japan of a continual decline of government as a source of R&D funding reversed itself in the 1990s. In the 1970s the Japanese government funded approximately 30 percent of total R&D. This government proportion declined at 5 percent annually throughout the 1980s, and represented only 16 percent of overall R&D by 1990. In that year, industrially funded research reached 78 percent of total R&D in Japan. Since 1992, however, government expenditures represent an increasing percentage of the total, while industry funding of R&D is declining as a percent of total R&D. By 1994, government support of total R&D reached almost 20 percent; industry declined to 73 percent (table A-4 and figure 5).

Figure 5. National R&D by source of funds: 1994

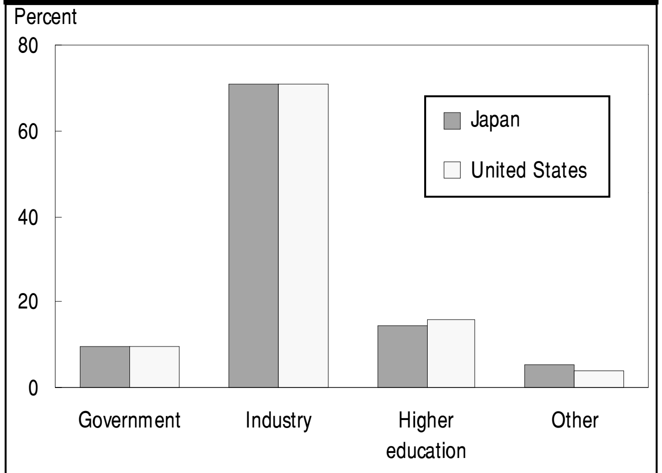


See appendix table A-4.

The government of the United States has been a more significant source of support for R&D than that of Japan if defense R&D is included. U.S. Government sponsored research grew rapidly in the 1980s, peaked in 1987, and has since declined, following the worldwide reductions in defense R&D since the late 1980s. U.S. Government support of overall R&D fell from 45.8 percent in 1985 to 35.0 percent in 1995 (table A-4).

In the performance of research, Japan and the United States have a similar pattern of shares of research performed by industry, higher education, and government (figure 6). Japanese industry increased its share to 76 percent of total research by 1990. In the past 5 years, however, industry research dropped to 72 percent of overall R&D, as universities and national laboratories have accounted for an increasing share of research performed in Japan. In the United States, the proportion of R&D performed by industry has increased from 68 percent in 1975 to a peak of 74 per-

Figure 6. National R&D expenditures by performer: 1994



See appendix table A-5.

increased from 68 percent in 1975 to a peak of 74 percent in 1985, with a slight decline since then. Coinciding with this industrial research was a decade-long trend in the United States toward a somewhat larger share of R&D performed by universities, from 11.6 percent in 1985 to 15.7 percent in 1994 (table A-5).

R&D by Character of Work

Based on OECD data, Japan and the United States report relatively similar proportions of basic, applied, and development work, with basic research having a slightly higher proportion of total R&D in the United States than in Japan. In 1992, 16.3 percent of R&D expenditures in the United States went to basic research. In that same year, 13.9 percent of R&D expenditures in Japan went to such research (table A-6). In the national survey of R&D, Japanese industry reports that they perform a significant amount of this basic research (about 37 percent).

Japan plans to increase its conduct of basic research and improve laboratory conditions in universities. The background to the Basic Law for Science and Technology states that the conditions for basic research in Japan are far below standards and conditions in the United States and Europe. The increase in the government funding of science is to improve these conditions, and to pursue frontier research in science and technology.

Scientists and Engineers

Japan has more engineers as a proportion of its overall labor force than the United States. In fact, relative to the size of its labor force, Japan has more engineers than any leading industrial nation except Sweden (NSF, 1996c). This engineering concentration stems from the large number of engineering degrees earned at the undergraduate level in Japan. (See section on Higher Education: undergraduate level.) In 1990, Japan had 342 scientists and engineers per 10,000 members of the non-academic labor force, compared with 281 for the United States in 1991. The engineering labor force in Japan is concentrated in fields of electrical and electronic engineering and computer processing technology (table 1). Based on the large number of engineering degree recipients entering the labor force each year, Japanese industries hire engineers in the services, manufacturing, and construction branches of their economy far more often than similar industries in the United States.

In contrast to large numbers of engineers, Japan still has relatively few employed scientists in their labor force. In 1991 the United States had 135 non-academic scientists per 10,000 members of the labor force compared with 104 in Japan in 1990, but the gap is narrowing (table 1).

The increasing concentration of science and engineering personnel in the Japanese labor force contrasts with the situation in the U.S. labor force. The stock of scientists and engineers relative to the labor force is sharply increasing in Japan; while only moderately increasing for scientists in the United States. The Japanese stock of scientists and engineers grew 8.0 percent annually from 1985–90 (table 1). During the same time period, the Japanese labor force grew at 1.4 percent annually. In contrast in the United States, the stock of engineers remained stable between 1986 and 1991, at 146 per 10,000 of the labor force. The U.S. stock of scientists relative to the labor force moderately increased from 109 per 10,000 of the labor force in 1986 to 135 per 10,000 in 1991, representing a 4-percent annual growth rate. The U.S. labor force grew 1.2 percent annually from 1986–91.

Table 1. Stock of scientists and engineers: various years /1

Category	Japan			United States		
	1980	1985	1990	1980	1986	1991
Scientists and engineers, total	940,301	1,514,200	2,224,347	2,369,200	3,047,000	3,560,000
Per 10,000 labor force 2/	166	252	342	218	255	281
Engineers	744,380	1,124,300	1,549,776	1,486,400	1,749,000	1,846,000
Per 10,000 labor force	132	187	238	137	146	146
Civil 3/	351,929	485,400	719,167	214,300	233,000	223,000
Electrical/electronic	119,499	233,100	318,277	351,600	550,000	562,000
Industrial and mechanical 4/	272,952	405,800	512,332	920,500	966,000	1,061,000
Scientists	195,921	389,900	674,571	882,800	1,298,000	1,714,000
Per 10,000 labor force	35	65	104	81	109	135
Natural	63,729	67,100	110,364	471,400	420,000	466,000
Computer	129,764	320,500	558,463	192,100	580,000	876,000
Social	2,428	2,300	5,744	219,400	298,000	372,000

1/ Non-academic scientists and engineers employed as scientists and engineers.
2/ Table A-7 shows labor force numbers used for each country, based on OECD data.
3/ Civil engineering includes surveying and architects.
4/ Industrial/mechanical engineering includes agriculture and forest technology, chemical, mechanical, metallurgical, mining, and other engineering and technology.

SOURCES: National Science Foundation, Division of Science Resources Studies, The *Science and Technology Resources of Japan: A Comparison with the United States* (Washington, D.C.: NSF 88-318); U.S. Bureau of the Census, Center for International Research, *Scientists and Engineers in Industrialized Societies* (Washington, D.C.: U.S. Bureau of the Census, 1992) and *Scientists and Engineers in* Japan: *1990* (Washington, D.C.: U.S. Bureau of the Census, 1996). See Technical Notes for differences in sample size used for tabulations in these publications.

The United States, however, has more women scientists and engineers in the labor force than does Japan. In the United States, women account for 38 percent of the non-academic scientists and 8 percent of the non-academic engineers. In Japan, women hold only 15 percent of the non-academic science positions and 3 percent of the engineering positions (table 2).

Distinct from the total stock of scientists and engineers is the number who are currently active in R&D. Two decades ago, the United States had more scientists and engineers engaged in R&D relative to its labor force than did Japan. These positions have reversed in the 1990s. Although the United States still has about twice the number of research scientists and engineers as does Japan, relative to the size of its labor force, Japan now has more research scientists and engineers than the United States. In 1993, Japan had 80 research scientists and engineers per 10,000 of the labor force. In that same year, U.S. researchers numbered 74 per 10,000 of the labor force. In Japan, a long-term trend of a 4-percent annual growth rate of active research scientists and engineers continued

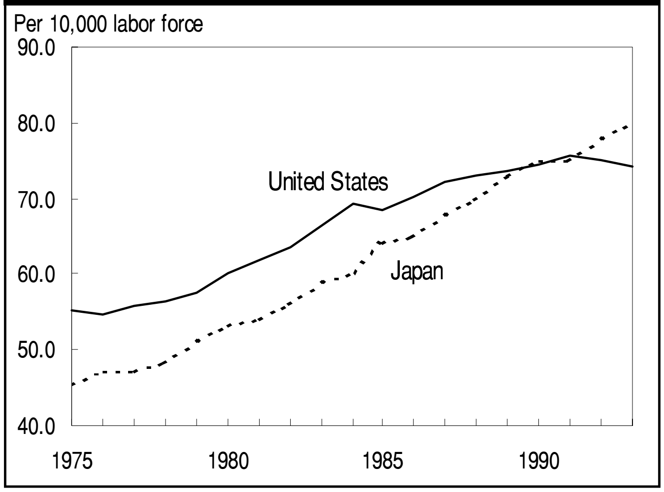
Table 2. Employed (non-academic) scientists and engineers, by sex

Category	Japan (1990)		United States (1991)	
	[Number]	[Percent]	[Number]	[Percent]
Scientists and engineers				
Total	2,224,347	100.0%	3,560,000	100.0%
Male	2,079,527	93.5	2,760,000	77.5
Female	144,820	6.5	800,000	22.5
Scientists	674,571	100.0	1,714,000	100.0
Male	570,724	84.6	1,066,000	62.2
Female	103,847	15.4	648,000	37.8
Engineers	1,549,776	100.0	1,862,000	100.0
Male	1,508,803	97.3	1,694,000	90.9
Female	40,973	2.7	152,000	8.1

SOURCES: U.S. Bureau of the Census, Center for International Research, *Scientists and Engineers in Industrialized Societies* (Washington, D.C.: U.S. Bureau of the Census, 1992) and *Scientists and Engineers in Japan: 1990* (Washington, D.C.: U.S. Bureau of the Census, 1996). See Technical Notes for differences in sample size used for tabulations in these publications.

throughout the period from 1975–93. The number of research scientists and engineers in the United States showed comparable growth from 1975–91, but has since grown more slowly. Growth in employment of research scientists and engineers in the United States was less than 1 percent (average annual increase) between 1990 and 1993 (table A-7 and figure 7).

Figure 7. Scientists and engineers in R&D



See appendix table A-7.

The Japanese have a higher percentage of their R&D scientists and engineers (RSEs) working in the higher education sector than does the United States, 21.8 percent versus 13.3 percent, respectively (table 3). As in the United States, relatively few of Japan's RSEs are employed in government laboratories. Under the new legislation, the Japanese government is focusing particularly on the scientists and engineers in universities and national laboratories—numbering approximately 145,000—to create for them an environment more conducive to breakthrough research (table 3). The government R&D section describes new competitive funding programs aimed at enhancing the capacity for basic research, mainly in the university sector.

The number of permanent government researchers will not increase as the government budget for science increases, so a very significant component of the new programs is the ability of faculty and directors of national laboratories to hire postdoctorate researchers and research assistants. In fact, the total number of government employees will likely decrease by some percentage each year as the Japanese government

Table 3. Number of scientists and engineers engaged in R&D by sector: 1993

Sector	Japan	United States	Japan	United States
	[Number]		[Percent]	
Total	526,501	962,700	100.0%	100.0%
Industry	367,278	764,500	69.7	79.4
Higher education	114,582	128,000	21.8	13.3
Government and private non-profit	29,907	60,000	5.7	6.2
Other	14,734	10,200	2.8	1.1

NOTE: Japanese data are based on OECD adjusted numbers for full time equivalents (FTE).

SOURCES: Organization for Economic Co-operation and Development,Technology Indicators, Paris, OECD, 1995; Government of Japan, National Institute of Science Main Science and and Technology Policy, Science and Technology Agency, *Science and Technology Indicators*: *1994*, NISTEP Report No. 37 (Tokyo, 1995); Science Resources Studies Division, National Science Foundation, *National Patterns of R&D Resources: 1996* (Arlington, VA: NSF, 1996).

decreases its hiring and the ceiling on S&E personnel in national laboratories (Ichikawa, 1996). Thus, new programs, which include funding for research assistants and postdoctorate positions, provide research directors the opportunity to expand their activity. While lifetime employees in universities will decrease, opportunities for fixed-term appointments (of various lengths of time) will increase. The Japanese government plans to fund about 10,000 graduate and postdoctoral positions a year.

Reforms for S&E personnel are also underway at the National Personnel Authority (NPA), which tightly controls hiring of research personnel for all national universities and national research institutes. There is currently a civil service entrance examination and a set of interviews that regulate the hiring of any professor or research scientist at national universities or institutes. Reforms are being discussed to deregulate personnel hiring in the academic sector over the next several years, so that national universities and institutes could hire scientists they want to have for their particular research strengths or teaching skills (Ichikawa, 1996).

Chapter 2. Government R&D

In the 1990s, the government is the dynamic growth sector of R&D in Japan. The Japanese government increased its share of overall R&D support from 16 percent in 1990 to 20 percent in 1994 (table A-4). In 1995, the Japanese government provided two supplemental budgets for R&D that together added \$3.5 billion[9] for funding competitive research in universities, improving university research facilities, computer networks, and large-scale R&D equipment and facilities.

The Basic Plan for S&T of 1996 suggests that the government allocate 117 trillion yen (equivalent to approximately \$74 billion in constant dollar terms) to R&D from 1996 to 2000. For Japan to meet the suggested investment of \$74 billion would require an average annual growth rate of around 10 percent in government R&D investments, far higher than past annual funding increases. Historically, Japanese government R&D expenditures have grown about 4 percent annually, from \$4.8 billion in 1975 to \$8.9 billion in 1990. However, Japan's government R&D investments accelerated somewhat in the more recent period between 1990 and 1995, at 5 percent annually. Additionally, in 1996 the Japanese government increased its R&D budget by 12.5 percent, reaching \$12.2 billion.

Using the 1996 government budget as a base year, a linear growth in the government R&D investment required to allocate \$74 billion would be an increase of approximately \$1.5 billion each year from 1996 to 2000 (table 4). The suggested amount of \$74 billion would represent a sizable increase (35 percent) over the amount spent in the previous 5 years, approximately \$51 billion in constant dollars from 1991–95. The Cabinet-approved 1997 R&D budget represents a 6.8-percent increase over 1996. The rate of increases in the 1996 and 1997 budgets together effectively meet the required level of growth. If Japan continues the trends of the 1996 budget and the approved 1997 budget, the year 2000 budget, or shortly thereafter, could meet the doubling goal.

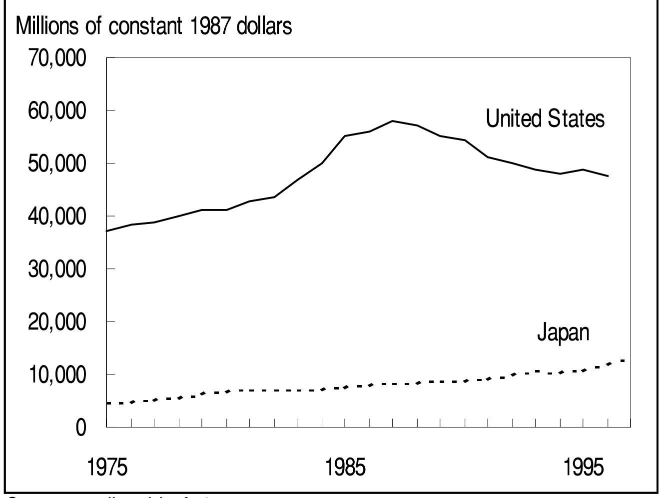
Table 4. A linear estimation of Japan's proposed increases in government R&D

Year	Constant 1987 dollars
	[Millions]
1996	\$12,198
1997	13,444
1998	14,817
1999	16,331
2000	18,000

SOURCE: NSF/SRS estimation.

In contrast to the trend in Japan of increasing government support for R&D, the 10-year trend for government sponsored research in the United States has been a declining real budget. At the peak of public funding for research in 1987, the U.S. Government invested \$57.9 billion constant 1987 dollars. In preliminary data for 1997, U.S. government investment decreased to \$47 billion (figure 8). Over this same time period, the U.S. Government decreased its share of overall R&D support from 46.2 percent to 33.6 percent (table A-4).

Figure 8. Government-funded R&D



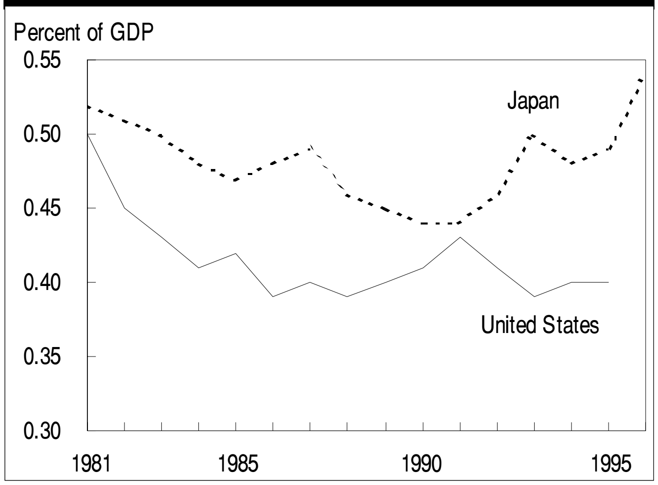
See appendix table A-4.

Although the U.S. Government spends more on R&D in absolute terms, relative to the size of its GDP, the Japanese government has outspent the U.S. Government in non-defense R&D for more than a decade (table A-3). In 1975, governments in both the United States and Japan were investing the equivalent of about 0.5 percent of their respective GDPs in nondefense R&D. Government funded civilian R&D as a percent of GDP declined both in Japan and in the United States throughout the 1980s, followed by an increase in support of nondefense R&D in the 1990s. However, from 1990–96, Japan had a higher annual rate of

[9] This is in addition to the Japanese government's \$10.9 billion budget for science in 1995.

growth (5.9 percent) in its government budget for civilian research than the United States (1.5 percent). By 1996, Japanese government civilian R&D rose to 0.54 percent of GDP; that of the United States represented 0.40 percent of GDP (figure 9 and table A-3).

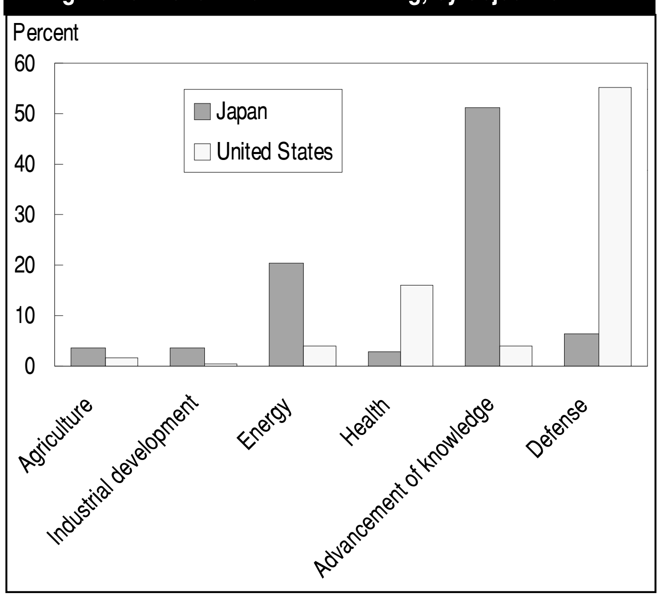
Figure 9. Government nondefense R&D/GDP ratio



See appendix table A-3.

The Japanese government spends the largest portion of its R&D budget—an estimated 51 percent—on the general objective of "advancement of knowledge," a general function which includes general university research funds (GUF), and should not be equated with basic research (figure 10). The U.S. Government funds the majority of its R&D budget on defense—55.3 percent in 1994—down from 67.5 percent in 1985. The second most important objective of government R&D funding in the United States is health research, approximately 17 percent.

Figure 10. Government R&D funding, by objective: 1994



NOTE: In Japan, advancement of knowledge includes general university funds and faculty salaries.

See appendix table A-8.

The emphasis of the Japanese government on various R&D objectives has been relatively stable throughout the past decade, except for an increase in energy, advancement of knowledge, and defense.

The relative share of agricultural research declined to compensate for these increases (table A-8). In this same time period, the U.S. Government increased its support of general science and health research, and decreased its support of defense research.

Organization of S&T Policymaking

The four most important organizations for S&T policymaking in Japan are the Prime Minister's Council for Science and Technology (CST), the Science and Technology Agency (STA), and two ministries: the Ministry of Education, Science, Sports and Culture (herein referred to as Monbusho), and the Ministry of International Trade and Industry (MITI). CST, composed of cabinet ministers and agency heads (e.g., Finance, Monbusho, STA, and the Economic Planning Agency), as well as representatives from universities and industry, advises the Prime Minister's office on long-term research goals. The role of the CST is becoming more important. In 1992, the CST provided the framework for the current S&T policy called, "General Guidelines for S&T," reemphasizing the importance of focusing on basic research. CST, chaired by the Prime Minister, with a secretariat within STA, is attempting to coordinate science programs across all ministries, and is considering the possibility of integration of science programs across government agencies. Such integration of programs may be discussed in future plans (Ito, 1996).

One difference between Japan and the United States in funding R&D is that the above mentioned main Japanese science agencies use intermediate organizations to carry out their funding and selection of proposals. (U.S. science agencies, such as the National Science Foundation and the National Institutes of Health, fund the research community directly.) For example, Monbusho administers its fellowship programs for doctoral students, postdoctorate researchers and international exchange of scientists, as well as its newly initiated "Research for the Future" funding program, through the Japan Science and Technology Corporation (JST).[10] Several STA programs are implemented by the Japan Development Research Corporation (JDRC). The Agency of Industrial Science and Technology (AIST) and the New Energy and Industrial Technology Development Organization (NEDO) carry out a variety of MITI's science programs. Thus funding targets for a program can sometimes be described in terms of the implementing agency. For example, under the S&T Basic Plan for 1996, "There is a target of funding 10,000 JSPS fellowships[11] for postdoctorates and graduate students by the year 2000." (See section on Academic Research.)

Within the Science and Technology Basic Plan of 1996, the S&T structure has remained relatively unchanged, but component parts are expected to work together (figure 11). There is greater cooperation among Monbusho and the other main science agencies. Plans presented to the Ministry of Finance between June and August of 1996 dealt with technical improvements and means to remove barriers among the three major science ministries. For example, for the first time, STA and MITI may directly fund research projects in universities. This level of cooperation between agencies is a new development (Ito, 1996).

New funds have been provided to the main S&T agencies for new basic research programs, often referred to as "basic strategic research" (table 5). This term for basic research reflects Japan's view of its need to invest in basic research as an overall strategy; it does not refer to targeting certain areas. In addition to these new programs, science and technology agencies are implementing a range of policies which give priority to the following four areas:

- improving the scientific research environment of universities and national laboratories by increasing and diversifying sources of funding, and upgrading facilities and equipment;
- promoting the training of researchers through improvements of graduate schools, enlarging fellowships, and facilitating researcher mobility;
- improving joint research systems and developing centers of excellence; and
- contributing to international scientific research through support for exchange of scholars and international research.

Table 5. Government funding of new programs for basic strategic research: 1996

Agency	Yen	Constant 1987 yen	Dollars 1/	Constant 1987 dollars
	[Millions]			
Total	¥32,000	¥29,329	$172	$140
Science and Technology Agency	15,000	13,748	81	65
Monbusho	11,000	NA	59	48
Ministry of International Trade and Industry	2,650	2,429	14	12
Other ministries	3,350	3,070	18	15

1/ All dollar amounts for R&D in this report use PPP conversion rates.

KEY: NA = not available

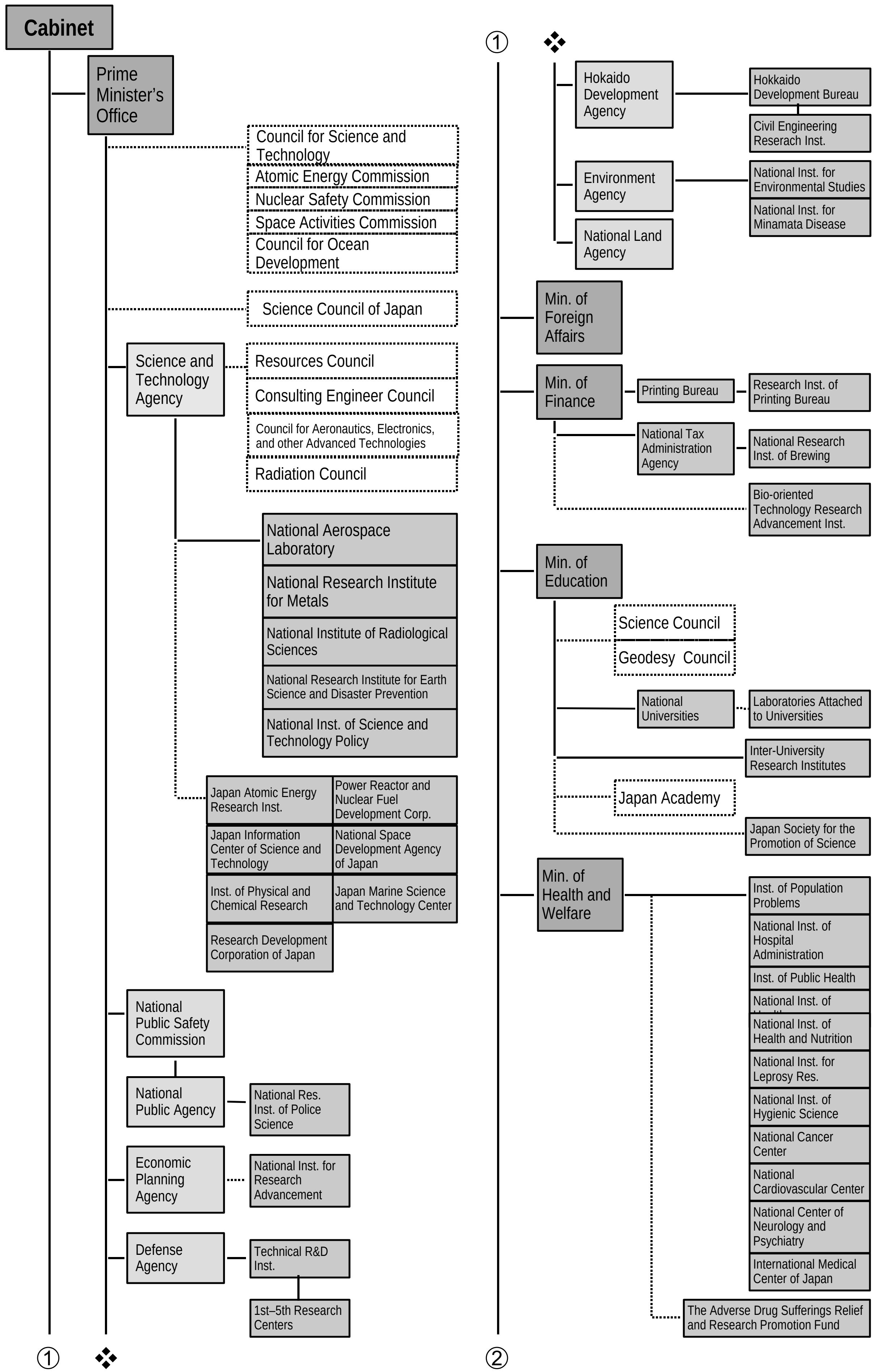
SOURCE: Science and Technology Agency, Research and Development Promotion Division, unpublished tabulations, 1996.

Ministerial R&D budgets are composed of: (1) funds for ongoing research-related operations and personnel costs of government research institutes and higher educational institutions, and (2) funds for research promotion-primarily in the form of external grants.

Monbusho and STA have the largest budgets, accounting for 49 percent and 26 percent, respectively, of the government's total R&D budget (figure 12). MITI is the third largest science funding agency (12 percent), followed by the Defense Agency (6 percent), the Ministry of Agriculture (4 percent), and the Ministry of Health and Welfare (3 percent). Most of Monbusho's funds are committed to the ongoing operations of the university system, including general university funding, as previously described.

[10] The Japan Development Research Corporation (JDRC) was recently combined with JICST to form the Japan Science and Technology Corporation (JST).

[11] The fellowship total of 10,000 will include positions funded by JSPS (the largest number) and by STA (through JST) and MITI (through NEDO).



Cabinet
Prime Minister's Office
Council for Science and Technology
Atomic Energy Commission
Nuclear Safety Commission
Space Activities Commission
Council for Ocean Development
Science Council of Japan
Science and Technology Agency
Resources Council
Consulting Engineer Council
Council for Aeronautics, Electronics, and other Advanced Technologies
Radiation Council
National Aerospace Laboratory
National Research Institute for Metals
National Institute of Radiological Sciences
National Research Institute for Earth Science and Disaster Prevention
National Inst. of Science and Technology Policy
Japan Atomic Energy Research Inst.
Power Reactor and Nuclear Fuel Development Corp.
Japan Information Center of Science and Technology
National Space Development Agency of Japan
Inst. of Physical and Chemical Research
Japan Marine Science and Technology Center
Research Development Corporation of Japan
National Public Safety Commission
National Public Agency
National Res. Inst. of Police Science
Economic Planning Agency
National Inst. for Research Advancement
Defense Agency
Technical R&D Inst.
1st–5th Research Centers
①
❖
①
❖
Hokaido Development Agency
Hokkaido Development Bureau
Civil Engineering Reserach Inst.
Environment Agency
National Inst. for Environmental Studies
National Inst. for Minamata Disease
National Land Agency
Min. of Foreign Affairs
Min. of Finance
Printing Bureau
Research Inst. of Printing Bureau
National Tax Administration Agency
National Research Inst. of Brewing
Bio-oriented Technology Research Advancement Inst.
Min. of Education
Science Council
Geodesy Council
National Universities
Laboratories Attached to Universities
Inter-University Research Institutes
Japan Academy
Japan Society for the Promotion of Science
Min. of Health and Welfare
Inst. of Population Problems
National Inst. of Hospital Administration
Inst. of Public Health
National Inst. of
National Inst. of Health and Nutrition
National Inst. for Leprosy Res.
National Inst. of Hygienic Science
National Cancer Center
National Cardiovascular Center
National Center of Neurology and Psychiatry
International Medical Center of Japan
The Adverse Drug Sufferings Relief and Research Promotion Fund
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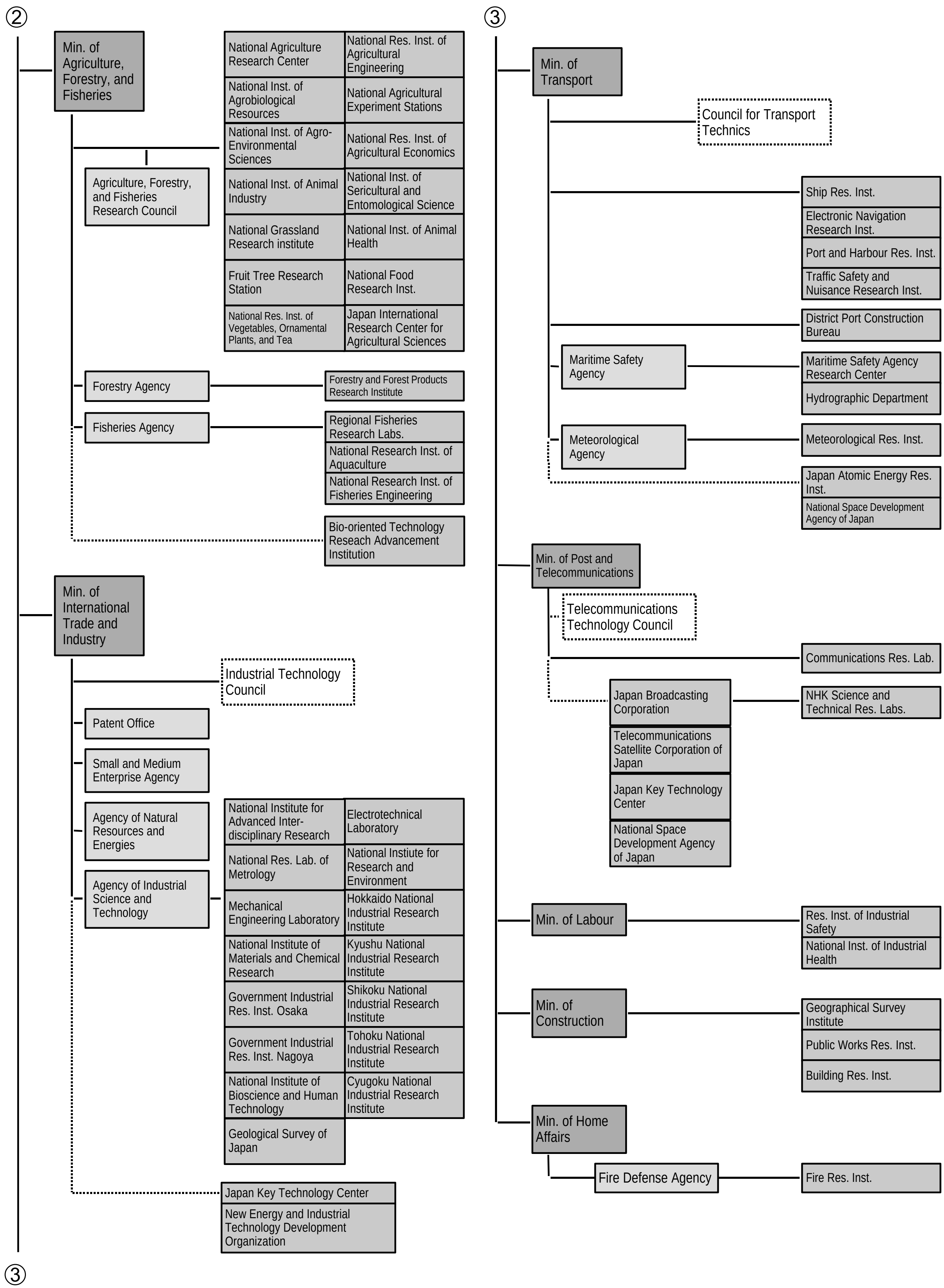
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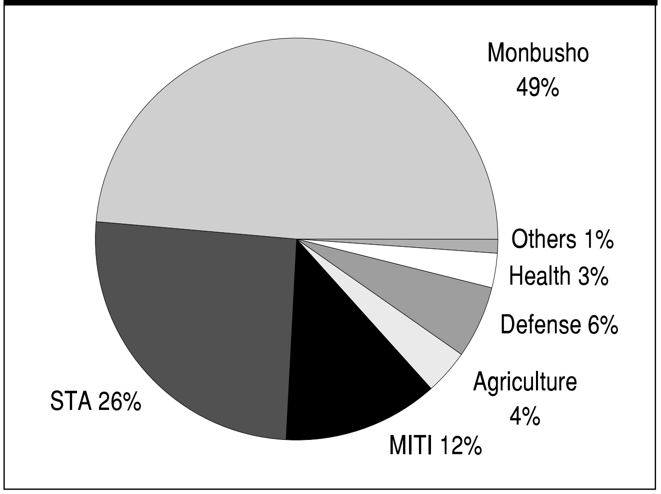
Min. of Agriculture, Forestry, and Fisheries
National Agriculture Research Center
National Res. Inst. of Agricultural Engineering
National Inst. of Agrobiological Resources
National Agricultural Experiment Stations
National Inst. of Agro-Environmental Sciences
National Res. Inst. of Agricultural Economics
National Inst. of Animal Industry
National Inst. of Sericultural and Entomological Science
National Grassland Research institute
National Inst. of Animal Health
Fruit Tree Research Station
National Food Research Inst.
National Res. Inst. of Vegetables, Ornamental Plants, and Tea
Japan International Research Center for Agricultural Sciences
Agriculture, Forestry, and Fisheries Research Council
Forestry Agency
Forestry and Forest Products Research Institute
Fisheries Agency
Regional Fisheries Research Labs.
National Research Inst. of Aquaculture
National Research Inst. of Fisheries Engineering
Bio-oriented Technology Reseach Advancement Institution
Min. of International Trade and Industry
Industrial Technology Council
Patent Office
Small and Medium Enterprise Agency
Agency of Natural Resources and Energies
Agency of Industrial Science and Technology
National Institute for Advanced Inter-disciplinary Research
Electrotechnical Laboratory
National Res. Lab. of Metrology
National Institue for Research and Environment
Mechanical Engineering Laboratory
Hokkaido National Industrial Research Institute
National Institute of Materials and Chemical Research
Kyushu National Industrial Research Institute
Government Industrial Res. Inst. Osaka
Shikoku National Industrial Research Institute
Government Industrial Res. Inst. Nagoya
Tohoku National Industrial Research Institute
National Institute of Bioscience and Human Technology
Cyugoku National Industrial Research Institute
Geological Survey of Japan
Japan Key Technology Center
New Energy and Industrial Technology Development Organization
③
③
Min. of Transport
Council for Transport Technics
Ship Res. Inst.
Electronic Navigation Research Inst.
Port and Harbour Res. Inst.
Traffic Safety and Nuisance Research Inst.
District Port Construction Bureau
Maritime Safety Agency
Maritime Safety Agency Research Center
Hydrographic Department
Meteorological Agency
Meteorological Res. Inst.
Japan Atomic Energy Res. Inst.
National Space Development Agency of Japan
Min. of Post and Telecommunications
Telecommunications Technology Council
Communications Res. Lab.
Japan Broadcasting Corporation
NHK Science and Technical Res. Labs.
Telecommunications Satellite Corporation of Japan
Japan Key Technology Center
National Space Development Agency of Japan
Min. of Labour
Res. Inst. of Industrial Safety
National Inst. of Industrial Health
Min. of Construction
Geographical Survey Institute
Public Works Res. Inst.
Building Res. Inst.
Min. of Home Affairs
Fire Defense Agency
Fire Res. Inst.

Figure 12. R&D budget share of Japanese ministries and agencies: 1994



See appendix table A-9.

Main Science Funding Agencies

Monbusho

With approximately one-half of the Japanese government R&D budget in 1994, Monbusho is responsible for promoting science at all levels of education, as well as funding university research, attached laboratories, and national inter-university research institutes. Several of the latter joint-use laboratories were established by Monbusho in the second half of the 1980s to upgrade university research facilities, and to provide access to researchers from all national universities. These include the Institute of Statistical Mathematics, the National Astronomical Observatory, and the National Institute for Fusion Science.

In the 1970s, Monbusho financed the building of new universities and research facilities, such as Tsukuba University and the National Laboratory for High Energy Physics (KEK). The science policy in the 1980s was focused on halting further expansion of universities and decreasing budget ceilings (universities would get less than the previous year). The expansion of facilities' budgets in the 1990s is primarily to upgrade obsolete university facilities rather than build new ones.

Supplemental budgets in 1993 and 1995, requested from the Diet (Japanese Parliament), provided large increases for research facilities as economic stimulus packages. In 1993, the supplemental budget of 560 billion yen (2.4 billion dollars) was used for much-needed improvements in university equipment and facilities. In 1995, the supplemental budgets for science, amounting to 680 billion yen (almost 3 billion dollars), allowed agencies to shorten the construction period of "big science" facilities and to provide additional fellowships for foreign and domestic scholars.

The Central Council for Education, Monbusho's most important body for forming education policy, recommended revitalizing Japanese universities with major funding increases. In 1995, Monbusho increased its competitive grants-in-aid program to university professors within national universities to approximately $440 million. These additional funds allowed them to apply for, and obtain, larger competitive grants than previously had been available for university researchers. As reported in the 1996 national R&D survey, these competitive grant funds in 1995 were in addition to the more than $3 billion Monbusho provided for base salaries and university research at these institutions through formula funding (table 6).

Monbusho uses the Japan Society for the Promotion of Science (JSPS) to administer its fellowships for doctoral students and postdoctorate researchers, as well as the new Research for the Future program for university research.

As with all the major science organizations in Japan, Monbusho has advisory boards with representatives from the science community in both industry and academia. For example, Monbusho's University Council provides advice on matters concerning universities through several working groups. One of these groups provided a forecast of S&E personnel needs in 1991 at the height of Japan's economic growth period, that was very optimistic about industry's future demand for highly trained personnel. This report of the University Council was the basis for Monbusho expanding graduate programs and increasing the limits on graduate student admissions.

Science and Technology Agency (STA)

The STA is responsible for funding a number of national laboratories, such as the National Aerospace Laboratory and the National Institute of Science and Technology Policy. (See figure 11 for the list of laboratories under each science agency.) They also fund big science facilities such as the RIKEN Ring Cyclotron and deep-sea research vessels, as well as competitive

Table 6. Research in natural science and engineering, conducted at national universities, by source of funding

	Formula funding		Competitive funding			
Year	Total funding	Monbusho 1/	Total competitive	Monbusho	Other government /2	Industry
	[Millions of constant 1987 dollars]					
1982	$2,568	$2,171	$396	$198	$150	$49
1983	2,655	2,261	394	198	138	58
1984	2,749	2,348	400	203	130	68
1985	2,825	2,382	443	206	140	97
1986	2,792	2,338	454	214	141	100
1987	2,894	2,405	489	231	150	109
1988	3,117	2,591	526	244	156	127
1989	3,132	2,564	567	253	168	146
1990	3,199	2,616	584	262	170	152
1991	3,354	2,720	634	283	180	172
1992	3,430	2,749	681	319	182	180
1993	3,672	2,917	755	360	198	197
1994	4,127	3,297	830	403	222	205
1995	4,038	3,164	875	442	237	195

1/ Includes both university salaries and formula funding of research.
2/ Includes STA and MITI funds.

SOURCE: Government of Japan, *Report on the Survey of Research and Development,* Statistics Bureau, Management and Coordination Agency, Annual Series.

grants-in-aid funding programs. The STA also contributes to formation of government science policy through detailed surveys of research areas, and produces an annual "White Paper on Science and Technology," which presents the results of these surveys.

Throughout the 1980s STA provided large funding and sophisticated equipment to its national laboratories, and they also experimented with a new funding mechanism for interdisciplinary basic research in strategic areas. This program of Exploratory Research for Advanced Technology (ERATO), managed by JST, sought to improve the quality of research in the Japanese system by bringing together university professors, industry researchers, and scientists from national laboratories. Under this scheme, researchers undertake a project for a 5-year duration. These programs required slowly changing the culture of science to move toward joint projects between industries and universities (Koizumi, 1993). (See "*ERATO Evaluation*" conducted by the NSF-supported Japanese Technology Evaluation Center (JTEC).)

STA's funding of competitive grants programs to promote basic research increased by more than $100 million from 1990–96. STA's list of 10 such programs (table 7) includes both established programs introduced in the 1980s, such as ERATO and the Frontier Research Program, as well as the new Strategic Basic Research Promotion. Most STA research funds are channeled through a number of public research corporations, such as the JST and the Institute of Physical and Chemical Research (RIKEN). (See *RIKEN's "Frontier Research*.") The International Joint Research Program, begun in 1989 and managed by JST, funds international collaborative basic research with other countries. Another STA funded program, begun in 1991, is the so-called Precursory Research for Embryonic Science and Technology System (PRESTO). This program is to fund a single individual for basic research, rather than the scientific teams funded in the above programs. While the ERATO projects were strictly off-campus, the 1996 basic research programs of STA and MITI can now directly fund university professors and build up the excellence of their university laboratories.

Table 7. STA programs promoting basic research							
Programs as listed in STA budget	1990	1991	1992	1993	1994	1995	1996
	[Millions of constant 1987 dollars]						
Total	$74	$88	$91	$95	$97	$147	$177
ERATO	23	25	28	33	32	38	34
Encouraging of basic research	6	6	6	6	6	9	9
Frontier Research Program (RIKEN)	10	16	12	12	14	28	22
Human Frontier Science Program	15	16	17	16	16	16	16
Basic Research Core System	5	5	5	5	5	5	3
Multicore Superconductive Project	12	11	11	9	8	9	10
Special Researchers' Program (RIKEN)	2	3	3	3	3	4	7
National Institute Post-doctoral Fellowship (JDRC)	1	2	4	5	5	7	10
Precursor Research for Embryonic S&T (PREST)	NA	2	4	6	7	8	1/
JDRC Strategic Basic Research Promotion	NA	NA	NA	NA	NA	22	65

1/ Included in Strategic Basic Research.

KEY: NA = not available

SOURCE: Science and Technology Agency, Research and Development Promotion Division, unpublished tabulation.

ERATO Evaluation

A U.S. panel of experts commissioned by JTEC to evaluate basic research under the ERATO program concluded that the research performed under ERATO is of high quality, with several projects leading to the development of world class research. ERATO introduced over a dozen new research directions in Japanese research. For example, under one ERATO project, a Japanese research group first realized that scanning tunneling microscopy (STM) could be used to pick up atoms one by one, to control matter on an atomic scale. A spinoff of this project is the Joint Research Center for Atom Technology (JRCAT), a 25-trillion yen, 10-year effort funded by MITI. The Director of JRCAT noted that, "ERATO was the precedent for this research" (Maruyama, 1996).

Besides carving out new research directions, ERATO also introduced new funding mechanisms of fixed-term projects and research structures in the Japanese S&T system that set a precedent for several other "ERATO type" programs that followed. ERATO funding mechanisms allowed STA to fund university professors for a 5-year commitment to a project; some professors took a leave of absence to head an ERATO project; others maintained their teaching while conducting the off-campus research. The new research structure allowed university and industry researchers, as well as scientists from national laboratories, to collaborate. Many ERATO projects were carried out within the Tsukuba Research Consortium near Tokyo. The 14-year experience with ERATO has increased mobility of researchers while providing 5-year fixed-term projects for young scientists.

RIKEN's Frontier Research

As one of the most highly regarded research organizations in Japan, RIKEN conducts multidisciplinary research, often in cooperation with international institutions and visiting foreign scientists. RIKEN, founded in conjunction with the Japan Atomic Energy Research Institute in 1917, was modeled on the German research institutes (now Max Planck Institutes). In physics, RIKEN is constructing a large-scale synchrotron radiation facility named SPring-8 (Super Photon Ring) in the Harima Science City in Hyogo Prefecture, about 35 miles west of Osaka. Upon completion in 1998, it will be the world's largest ultrahigh-brilliance X-ray synchrotron radiation facility, and available to researchers from Japan and abroad. In addition, through RIKEN, Japan will contribute to the $20-million collaboration in spin physics research at Brookhaven National Laboratory's Relativistic Heavy Ion Collider (RHIC) in the United States. When commissioned in 1999, RHIC will be the world's highest energy-collider of heavy ions, and also the highest energy collider of spin-polarized proton beams for physics research.

In 1986, RIKEN initiated the Frontier Research Program to support long-term basic science in such areas as brain research, new materials, and photodynamics. In 1994, there were 500 permanent researchers and nearly 2,000 visiting scientists. Among the priorities in the Japan science budget for 1997 is 10 billion yen ($43 million in constant dollars) for brain research, including brain mechanisms of mind and behavior, information processing, and neuronal functioning. RIKEN's facilities and expanded research programs have implications for U.S. collaborators. The Frontier Research Program recruits personnel from overseas as well as from Japan, and a number of non-Japanese team leaders hold supervisory positions (STA, 1995).

Ministry of International Trade and Industry

MITI played a key role in technology policy during the reconstruction of the Japanese economy after World War II. Technology policy began with a focus on meeting the requirements for industrial development in the 1950s and later shifted primarily to promoting international trade in the 1970s. MITI currently supports its own programs of industrial research and development through the Agency of Industrial Science and Technology (AIST). But in addition, MITI is supporting basic research and a more open exploration of possible innovations than had previously occurred. In 1995, the New Energy and Industrial Technology Development Organization (NEDO), which is affiliated to MITI, introduced a new grant scheme for large grants to researchers at university and government laboratories.

As part of Japan's effort to support future innovation through basic science, MITI created the National Institute for Advanced Interdisciplinary Research (NAIR) through the reorganization of existing laboratories, as well as the National Institute of Bioscience and Human Technology. NAIR is to contribute to the generic technology base for future industrial S&T. AIST has restructured R&D into the Industrial S&T Frontiers Program, which aims at technological breakthroughs by linking industry, academia, and government. Some of the research themes under this program are superconductivity, biotechnology, new materials, electronics, machinery, and human sensory perception. Under MITI's Frontiers Program, projects such as the Joint Research Center for Atom Technology (JRCAT) are experimenting with mechanisms for mixing scientists from universities, national institutes, and industry. (See "*Atom Technology*.")

Atom Technology

Under MITI's Industrial S&T Frontiers Program, the Joint Research Center for Atom Technology (JRCAT) has gathered approximately 100 scientists from a consortium of industries, national laboratories, and universities to conduct basic interdisciplinary research in atom technology. This technology is based on the invention of scanning tunneling microscopy (STM) by Rohrer and Binnig of IBM Zurich Research Laboratory. By this technique, it is possible to observe and transfer individual atoms. This frontier S&T area in material science spans work in new materials, electronics, biotechnology, and chemistry. The goal is to develop innovative structures and materials through manipulation and control of individual atoms and molecules. It is expected to have engineering applications related to catalytic reactions, defects and impurities in semiconductors, and electrode/colid interfaces (Maruyama, 1996).

A consortium of 30 Japanese firms, including Fujitsu, Hitachi, NEC, Sharp, Sony, and Toshiba, are contributing researchers (and a small annual fee) for participation in this program. JRCAT, located in MITI's National Institute for Advanced Interdisciplinary Research (NAIR) within Tsukuba, also receives 26 researchers from national laboratories in close proximity, mainly the Electrotechnical Laboratory and the National Institute of Materials and Chemical Research. The JRCAT budget is 25 trillion yen for 10 years ($1.1 billion in constant dollars, or approximately $100 million per year), mainly funded by MITI. Funding received directly from MITI (10 percent) has many restrictions. The majority of MITI funding, through NEDO, gives the project the flexibility to hire university professors to lead key groups in this research, as well as postdoctorate researchers and technicians. The funding also provides for travel to one international meeting per year for each of the 100 researchers, for small workshops on specific topics, and for organizing and hosting a large international conference on atom technology. Postdoctorates include young researchers from Japanese industry and universities, as well as young foreign scientists.

For example, one experimental group of JRCAT is exploring new electronic materials and related physics for development of atom technology. The exploratory materials are 3rd transition metal oxides and organic molecular systems with specialized functions. This work will contribute to critical-state phase control on solid surface and solid materials. Results, reported in *Nature* in 1995, include a new oxide of manganese with interesting properties. By applying magnetic field resistance, the electrical conductivity of the material increases as much as 10 orders of magnitude. In the United States, the American Physical Society (APS) meeting in 1995 held a new session on this effect. A conference on this topic, colossal magneto resistance (CMR), was held in Tsukuba in 1996.

MITI is also attempting to revitalize the research conducted at its national laboratories. For example, in 1993 MITI consolidated several of its life science laboratories into the National Institute of Bioscience and Human-Technology, and then hired a leading university researcher as its Director-General. Through fundamental reforms in these national laboratories, MITI has the goal of encouraging biotechnology research that would match international standards.

CHAPTER 3. INDUSTRIAL R&D

Although government R&D budgets have recently increased, industrial laboratories still conduct the vast majority of Japan's research, funding nearly 75 percent of the total resources for R&D and employing nearly 70 percent of the research scientists and engineers (table A-4 and table 3). Until the economic recession of 1992, the annual R&D budget for the Japanese firm Hitachi alone equaled the total amount administered by the Ministry of Education (Monbusho) to university research (Barker, 1996). Large Japanese companies have built central laboratories for long-term strategic research. While academic science was in an impoverished state throughout the 1980s, corporate science flourished. Thus, corporate science dominates many fields in Japan.

The Japanese model of imported technology and adaptive R&D to rebuild its industry and technology following the devastation of World War II was very successful. Technological development was led by close cooperation between MITI and various industries. What is sometimes mistakenly perceived as "copying" from the West enabled Japan's significant industrial investment in R&D to adapt and extend technologies. The section below, Overall Industrial R&D Trends, provides some indicators of Japan's heavier industrial investment in R&D compared with that of the United States.

An important aspect of Japanese industrial R&D is to go beyond the limits of the technology—to make better and better products. For example, Japanese companies are world leaders in engineering very fine fibers, and also in bringing the purity of iron to extremely high levels. This type of research is especially appreciated in Japan. The pursuit of the extremes of a technology takes a consistency in R&D support, which Japanese industry has been willing to continue, sometimes for over 20 years, to accomplish a breakthrough (Hara, 1996). (See "*Toray Industries' Adaptive Research*" as an example of Japan's strong commitment to such research.)

Besides demonstrating a great consistency in research, Japanese industry has also provided life-long training to its scientists and engineers. Leading industries recruit very good students from high ranking universities and department chairs. Once hired, young researchers are given in-house education, attend international conferences, and are continuously in contact with academic and professional societies. Top young research scientists and engineers are encouraged to earn their doctorate through industry, called *ronbun,* or thesis doctorates. The majority of senior researchers in industry have *ronbon* doctorates; the minority of senior industrial researchers earned course-work doctorates in universities.

TORAY INDUSTRIES' ADAPTIVE RESEARCH

Toray Industries exemplify some of the corporate R&D strategies for competitiveness that have contributed to Japan's trade surplus in high technology products. Toray, a textile company established in 1923, purchased licensing agreements from Dupont (1953) for production of nylon, and from the United Kingdom (1971) for carbon fiber production.

Through 20 years of R&D in its advanced composite materials laboratories, Toray has produced carbon fiber products with the highest tensile strength in the world. Japan is now the biggest carbon fiber producer in the world, exporting half its production to the United States for use in the aircraft industry and for high quality sporting goods. When the United Kingdom sold Japan the licensing agreement for carbon fiber production, it did not envision all the large market applications of carbon fibers (Hara, 1996).

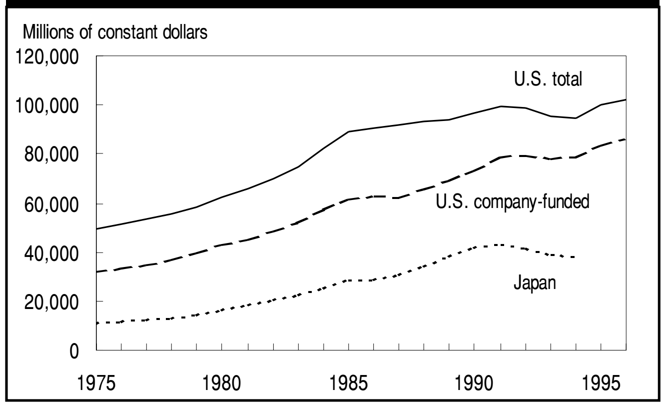
Industrial career development programs also include sending researchers to universities throughout the world—though mainly to the United States—for a period of 1–2 years as visiting researchers or doctoral students. In general, Japanese industrial researchers are sent abroad after obtaining their master's degrees, usually for 2–3 years, to top research universities that specialize in fields of particular interest to Japanese industry. For example, University of California at Irvine is often selected by Toshiba researchers for advanced training in biotechnology, machinery, and electronics, because of its close proximity to a large Toshiba factory that produces personal computers (Takayanagi, 1996).

Corporate laboratories also provide donations to leading Japanese national universities, are closely related to professors knowledgeable in specific fields of R&D, and hire their students. In some fields, such as electronics, researchers go to Japanese universities for advanced training, or to government research laboratories in Tsukuba Science City (Hara, 1996). In the past, donations of equipment and scholarship funds to universities and non-formal exchange of information have provided a loose coupling between industry and Japanese universities, but no strong involvement of university faculty in specific research projects. In contrast, professors in the United States are able to be directly employed by companies. Programs for industry—university joint projects are being established in Japan,[12] but regulations related to external payments to professors (who are civil servants) may require 2–5 years to resolve. (Takayanagi, 1996).

Overall Industrial R&D Trends

In both the United States and Japan, industrially funded R&D increased rapidly from 1975 to the peak year in 1991, followed by stagnant, or slightly declining, industrial R&D investments each year since then. Japanese industry investment in R&D rose from $11.4 billion in 1975 to $44 billion in 1991, representing an 8.9-percent average annual growth rate (table A-4). In the peak year of industrial support of R&D, 1991, private industry accounted for 78 percent of overall R&D in Japan. Industrially supported research in Japan declined an average of 3.1 percent annually from 1991–94. In the United States, industry investment in R&D rose from $32.2 billion in 1975 to $79.8 billion in 1992, representing an average-annual growth rate of 5.5 percent. In the United States, a slowdown in the economy resulted in a slight decline of industrial support of R&D in 1993–94. The average rate of decline was 1 percent over this period. More recent (preliminary) data for U.S. industrial R&D funding, however, show an expected 3.5-percent increase for 1995–96 (figure 13). The continued decline in Japanese industrial R&D stems from a prolonged economic recession.

Figure 13. National industrial R&D expenditures



See appendix tables A-4 and A-5.

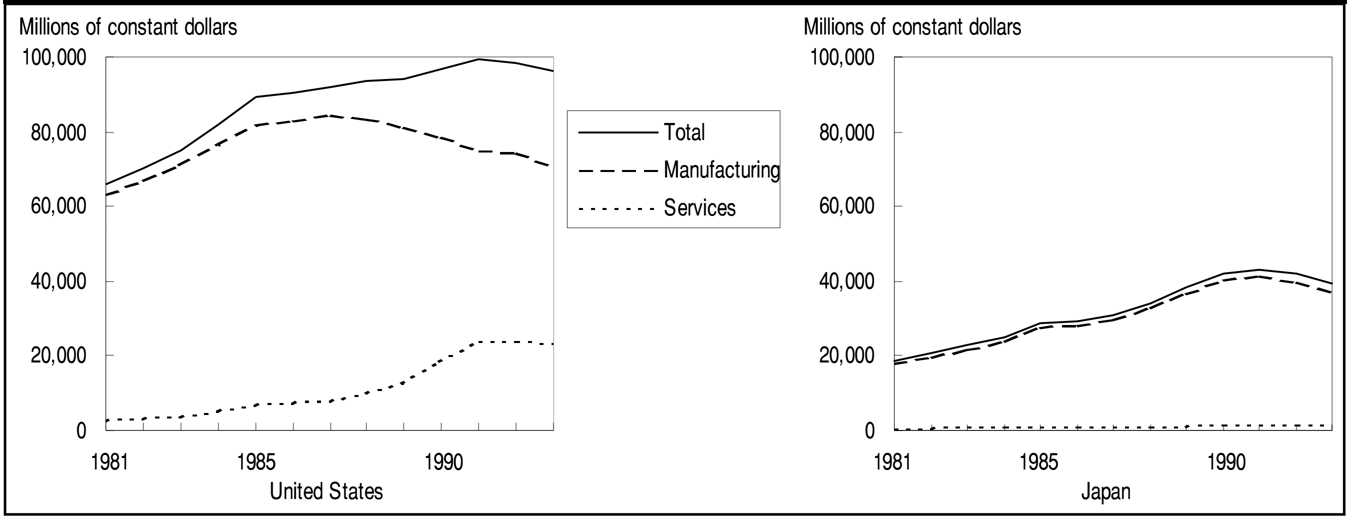
Declines in overall R&D were somewhat softened by increases in R&D in the service industries. U.S. industrial research in the manufacturing sector had strong growth in the early 1980s, level funding in the mid-1980s, and declining budgets every year since 1989. At the same time that manufacturing industries decreased their investments in R&D, service sector industries increased their R&D. In addition, part of R&D previously classified as manufacturing is now classified in service industries. By 1993, the service sector in the United States accounted for approximately one-quarter of industrial R&D (figure 14 and table A-10). In contrast, Japanese industrial R&D performance is highly concentrated in the manufacturing sector.[13]

As a percentage of Gross Domestic Product (GDP), Japanese industrial R&D doubled from 1975–90, and has declined slightly in the 1990s (table A-11). In 1994, the ratio of overall Japanese

[12] Subsequent to the Japanese student riots in the 1960s to protest industry interaction with universities, mainstream professors had little collaboration with industry. Since 1985, however, professors have again begun to collaborate with industry. Many projects are occurring, with strong industry—university collaboration.

[13] The Japanese service sector may not yet be well surveyed.

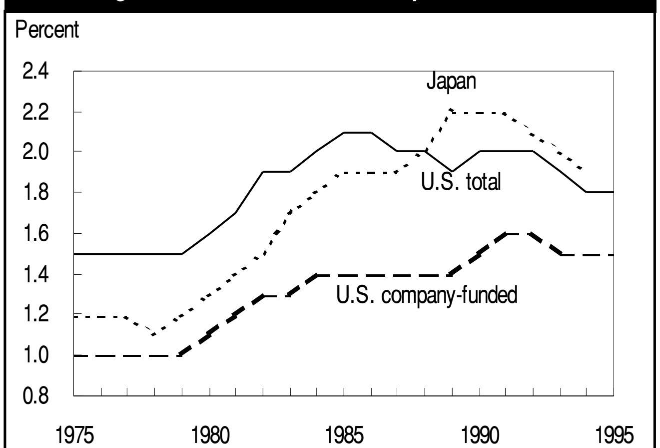
Figure 14. Industrial R&D performance, by sector



See appendix table A-10.

industrial R&D to GDP—1.9 percent—was comparable to the U.S. proportion of 1.8 percent. However, Japanese industrial R&D is almost entirely (98 percent) financed by companies themselves. This Japanese company-funded R&D as a percentage of GDP has surpassed the U.S. ratio of company-funded R&D to GDP every year since 1975. In 1994, company-funded R&D represented 1.9 percent of GDP in Japan and 1.5 percent in the United States (figure 15).

Figure 15. Industrial R&D as a percent of GDP



See appendix table A-11.

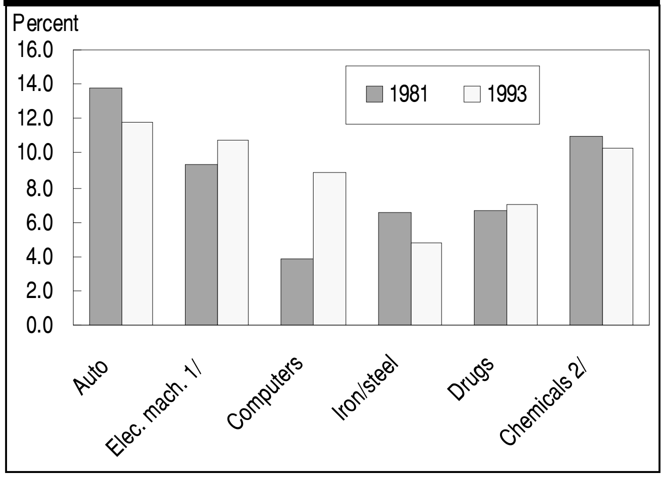
R&D Concentration in Manufacturing Industries

While Japanese manufacturing industries have maintained huge trade surpluses with neighboring countries in the region, the Asian developing economies are beginning to erode Japan's dominant economic position in many markets. In a 1994 survey, Japanese companies rated competition from Asia as one of their major concerns. Corporate R&D managers stressed that the "creation of distinctive high-value-added products through research" is one of the most important Japanese business strategies. Japan's future competitiveness in the region is viewed as being dependent on developing evermore advanced industries. Thus, there has been an emphasis on enhancing industry's science base, as well as a shift in the concentration of R&D into newer industries. The concentration on R&D in drugs and medicines, computers, and electrical machinery has increased, while that in automotive industries, chemicals, and the basic metals industry of iron and steel has decreased (figure 16).

In the 1990s, Japanese manufacturing industries' leading R&D areas (as a proportion of total R&D) continued to be in communications technology (including consumer electronics and all types of audio equipment), motor vehicles, and electrical machinery. But from 1990–93, R&D expenditure levels in these industries decreased, as did their share of overall industrial R&D. In contrast, Japan began to increase R&D funding levels and R&D personnel in drugs and medicine (figure 16).

Japanese industry was among the first to restructure its manufacturing through offshoring to European, Asian, and North American countries. As with most of the offshore production and outsourcing now occurring in other industrialized countries, the major R&D activity has remained in the firms' central laboratories

Figure 16. Japanese manufacturing R&D: 1981 and 1993



1/ Excludes communication equipment.
2/ Excludes drugs and medicines.

See appendix table A-110 and A-12.

in Japan. These central laboratories will continue to work on R&D innovations, while some small amount of marketing research will be conducted abroad. (See "*Nissan Offshore Manufacturing*" as one example of this trend, with R&D maintained in Japan's industrial laboratories.)

To a greater extent than in the United States, industrial R&D expenditures in Japan are concentrated on electrical and non-electrical machinery, radio, television, and communications equipment (table A-13 and figure 17).

By 1993, drugs and medicine had the highest R&D expenditures as a percent of net sales at 9.9 percent, compared with motor vehicles at 2.7 percent, or petroleum and coal at 0.9 percent (table A-13 and figure 18). R&D by non-manufacturing industries in Japan still comprises less than 5 percent of industrial R&D.

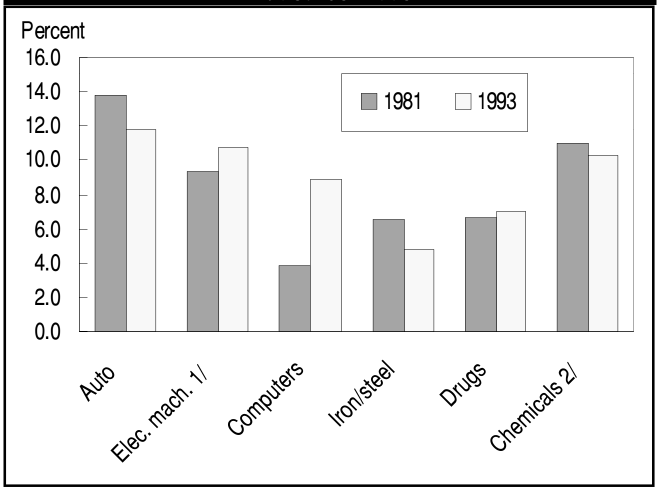
Nissan Offshore Manufacturing

To be free from money exchange rate problems caused by the sharp appreciation of the yen, Nissan has some production and R&D activity offshore. The production of automobiles abroad is mainly in the United States (Tennessee) and England, but also in Spain, Mexico, Thailand, Taiwan, and South Africa. Over 1,600,000 automobiles are produced in Japan; and 600,000 are produced abroad. The Tennessee facility produces 450,000 cars a year. The number of cars produced in England is restricted, but those produced are exported throughout Europe, and have 3 percent of the market share.

The main R&D facilities will remain in Japan, and Nissan central laboratories will continue the R&D necessary for cost reductions, such as low fuel consumption and low exhaust emissions. However, partial R&D work will be done abroad, in the United States and England, to design automobiles with local parts and local suppliers. To advance technology, some parts may be developed abroad. (Marumo, 1996).

While minimal research for particular companies will be conducted in the United States, opportunities exist for enhanced U.S.–Japanese collaborative R&D in the automotive industry. Discussions for collaboration are underway in the important area of intelligent highways. In the future, automobiles will be an even more intelligence-intensive product. Japan is collaborating with Europe and the United States on Intelligent Transport Systems (ITS) for automated highways of the future. One technical committee of the International Standards Organization (ISO) is working for standardization of these future intelligent systems. Five Ministries in Japan work on ITS, including among others, MITI, Construction, and Transportation. Japan's particular focus in automated highways is research on navigation systems for ITS (Maruma, 1996).

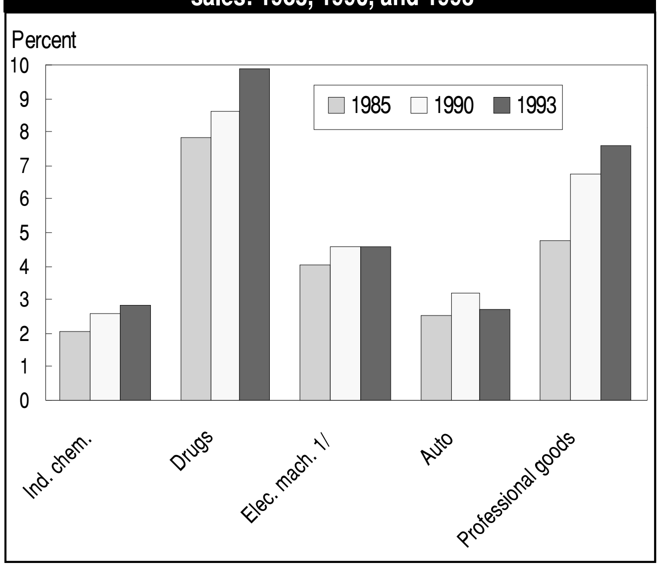
Figure 17. Proportion of R&D expenditures by selected industries: 1993



1/ Excludes communication equipment.
2/ Excludes drugs and medicines.

See appendix table A-12.

Figure 18. Japanese R&D expenditures as a percent of net sales: 1985, 1990, and 1993



1/ Excludes communication equipment.

See appendix table A-13.

U.S. leading R&D performers continue to be the aircraft and communications equipment industries, but these industries' share of overall industrial R&D fell during the last 10 years (NSB, 1996). In contrast, chemical industries, pharmaceutical companies, and companies primarily engaged in the manufacture of scientific instruments increased their share of industrial R&D. Far stronger growth, however, occurred in non-manufacturing industries in the United States, which now account for more than 25 percent of industrial R&D. R&D performed by computer software companies and companies providing communication services are examples of these service sector industries.

Industrial Scientists and Engineers Engaged in R&D

Corresponding to the strong growth in industrial funding of R&D activity in Japan and in the United States in the 1980s is the almost equally strong growth in the number of industrial scientists and engineers engaged in R&D. In each country, the number of industrial scientists and engineers increased at an average annual rate of growth of more than 5 percent. However, Japanese industry continued to increase their employment of scientists and engineers for research and development despite their economic recession in the 1990s. In the United States, industry decreased its employment of scientists and engineers in R&D by about 25,000 from 1992–94 (table A-14).

Japan has more R&D scientists and engineers per 10,000 employees in manufacturing companies than the United States. In 1993, Japan employed 622 RSEs per 10,000 employees in manufacturing companies, compared with 520 RSEs per 10,000 in the United States in that same year. This higher employment of RSEs in manufacturing companies in Japan has existed since 1985 (table A-15).

Industry–University Relations

Compared with the university sector, Japanese industry dominates as the preferred place for research and advanced training. Industry particularly strengthened its research capacity in the 1980s by attracting and training top graduates from Japanese universities, as well as by expanding industrial research facilities. Japanese industry interacts with both domestic and foreign universities, especially those in the United States.

For example, Japanese industry sends its research personnel to top U.S. universities for 1 to 2 years for advanced study in particular fields. Previously, few Japanese students remained long enough at U.S. universities to complete a doctoral degree. Instead, industrial researchers more likely returned to their company and earned a doctorate through corporate research. While Japanese industry continues to offer its employees the opportunity to earn their thesis doctorate through research in their corporate laboratories, U.S. universities also show recent small increases in the number of doctoral degrees in natural sciences and engineering earned by foreign doctoral candidates from Japan.[14]

Japanese industry is increasing its interaction with Japanese universities through donations and research contracts, and also is involved in the expansion of university-based doctoral programs. In the 1980s, some university professors worked jointly with industrial researchers on an area of strategic research under the ERATO programs. In the 1990s, Monbusho introduced Centers for Cooperative Research in Advanced S&T at some national universities in an effort to couple basic research in sciences with development activities in industry. Under this program companies send their researchers to complete a short Ph.D. degree useful to their R&D laboratory. For example, the interdisciplinary Research Center for Advanced Science and Technology (RCAST) at the University of Tokyo, which is a new Ph.D. program, receives many students from industry (researchers who have completed their master's degrees prior to employment). At RCAST, these doctoral students are required to switch to a field that is different from their master's program. Candidates enter fields in which their companies would like to expand research work. The cross-fertilization of different fields within a university-based doctoral program better prepares doctoral students to contribute to their company's new directions than does strictly within-industry training. Under the new 1996 basic research programs, industry now can conduct joint projects with university professors.

[14] Published tabulations of the U.S. Doctorate Record File do not show how many of the Japanese doctoral recipients are supported by Japanese industry.

CHAPTER 4. HIGHER EDUCATION

INSTITUTIONS

In contrast to the relatively recent development of higher education institutions in other Asian countries, Japan greatly expanded its institutions of higher education in the 1950s. By 1955, public institutions, including the national universities (totally funded by the national government), and local institutions (funded by the prefectures and municipal governments), numbered over 100. The total number of public institutions has not increased significantly since then. An additional 25 national and 15 local universities have opened in the last 40 years. In contrast, the number of private institutions has increased rapidly over the last few decades, growing to more than 400 in 1995, and representing approximately 75 percent of all higher education institutions (Monbusho, 1995a).

The largest numbers of graduate enrollments in Japan are in private schools, but national universities still dominate in the production of doctoral natural science and engineering (NS&E) degrees. About 30 of these national universities are considered research universities. The national universities account for about one-half of the social science doctoral degrees and 85 percent of the doctoral degrees in engineering, natural sciences, and agricultural sciences (Monbusho, 1995c). In the United States, research universities, which number about 88, also dominate in advanced degrees in science and engineering.[15] In 1993, students in the United States earned 75–85 percent of their master's and doctoral degrees in science and engineering at research universities (NSB, 1996).

TRENDS IN UNDERGRADUATE EDUCATION

ASSOCIATE DEGREES

In Japan, associate level programs are small compared with 4-year college and university programs. In 1994, student enrollment at the associate level numbered 550,000 compared with 2.2 million at the bachelor's level. Engineering students at the associate level in Japan attend two types of institutions: 5-year technical colleges or 3-year junior colleges. In 1994, these institutions each produced about 10,000 engineering degrees. Entrance level and characteristics of these institutions differ considerably. The far more numerous junior colleges (548) are predominantly private institutions with an enrollment that is 90 percent female; only 4 percent of their earned degrees are in engineering. The smaller number of technical colleges (62) are public institutions with an enrollment that is 80 percent male. Students enroll in 5-year technical colleges following completion of compulsory education, 9th grade.[16] The programs of technical colleges are aimed at training technicians and practical engineers.[17] In contrast, Japanese students enter junior colleges after completion of upper-secondary education, 12th grade.

Engineering departments in junior colleges, traditionally all male departments, sharply increased their rate of female enrollment between 1975 and 1990. Young women now comprise approximately 30 percent of the engineering student body at the junior college level, mainly in electrical and communications engineering and applied chemistry. While the number and percentage of females entering associate level engineering programs in junior colleges is increasing, it is from a small base (table 8). In addition, the Monbusho annual survey of education shows that the number of males entering such programs declined about 25 percent from 1975–93.

Recent declines may be influenced by demographic changes, as well as the decline in the 18-year-old population in Japan. With a declining college-age population, the number of 18-year-olds entering the university is dropping, down from a peak of 2.05 million in 1992 to an estimated 1.5 million in 2000. This demographic trend will continue until at least 2010. In con-

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[15] According to the Carnegie classification, U.S. research universities offer a full range of baccalaureate programs, are committed to graduate education through the doctorate degree, and give high priority to research. Research I universities receive at least $40 million annually in federal support and award at least 50 doctoral degrees. Research II universities meet similar conditions, but receive between $15.5 million and $40 million annually in federal support.

[16] Education in Japan becomes quite stratified at the upper secondary level, separating those who will go to junior colleges and universities from those who will enter vocational schools and technical colleges.

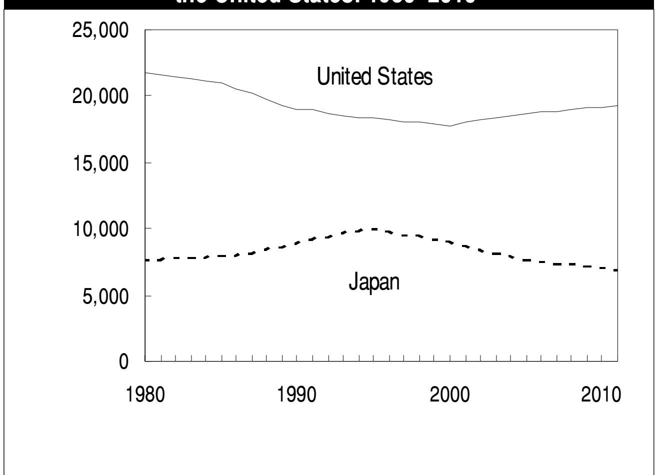
[17] Students in technical colleges may transfer to the upper division at the university where they would have two more years of study in order to graduate with a bachelor's degree.

Table 8. Female enrollments in engineering at the junior college level			
Year	Total	Female	
	[Number]	[Number]	[Percent]
1975	23,335	885	3.8%
1985	19,787	3,028	15.3
1990	24,843	7,272	29.3
1991	24,927	7,599	30.5
1992	24,794	7,718	31.1
1993	23,993	7,285	30.4

SOURCE: Government of Japan, Monbusho Survey of Education, Annual Series.

trast, in the United States, the college-age population declined earlier, starting in 1985, and it will continue to decline until the year 2000 (figure 19).

Figure 19. Population of 20- to 24-year-olds in Japan and the United States: 1980–2010



SOURCE: NSF/SRS, *Human Resources for Science and Technology: The Asian Region,* NSF 93-303, Washington, DC: NSF.

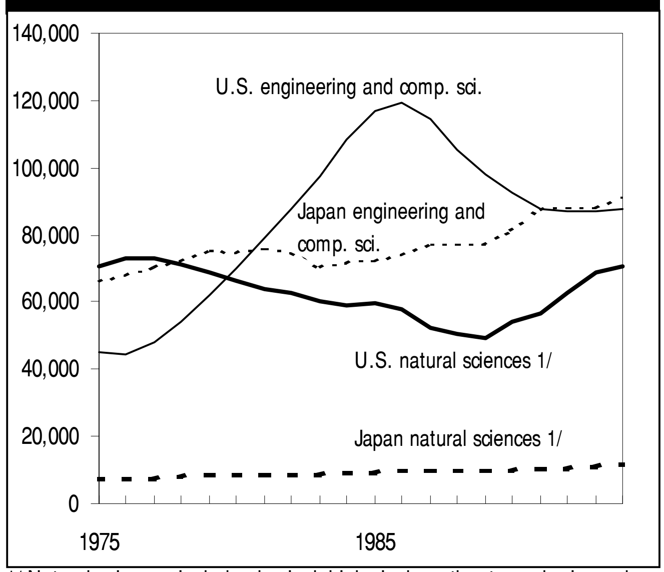
In the United States, most states have junior college courses, which will transfer from one institution to another within the state system. Taking and transferring courses are the *modus operandi* for the majority of students in the United States at two-year level institutions; only about 9 percent of those enrolled complete a 2–3-year program of studies and obtain a certificate of associate degree. In 1993, only 2,500 students completed associate degrees in engineering in U.S. higher education; another 40,000 earned engineering technology degrees. Transferring from technical colleges and junior colleges to universities in Japan, however, is not as prevalent as it is in the United States. In Japan, students in technical colleges "may" transfer to the upper-division at the university where they would have 2 more years of study in order to graduate with a bachelor's degree, but transferring is not the norm.

Bachelor's Degrees

Compared with the United States, a significantly higher proportion of Japan's undergraduate degrees are earned in engineering. Japanese undergraduate students earn 20 percent of their degrees in engineering fields,[18] far greater than the 5 percent of engineering undergraduate degrees earned in the United States. This concentration on engineering is partly explained by the greater number of engineering jobs in the labor market compared with the United States. (See Chapter 3 on international comparisons of scientists and engineers in the labor force.)

Differences in taxonomy, however, also partly explain the higher proportion of engineering majors. In Japan, engineering departments subsume computer science and also extend, to a smaller extent, to some applied fields of the natural sciences. For example, in Japan, solid-state physics is included in engineering; in U.S. universities, professors of solid-state physics are on faculties of the natural sciences. Given these differences in taxonomy, an approximate comparison of

Figure 20. B.S. degrees: 1975–94



1/ Natural sciences include physical, biological, earth, atmospheric, and oceanographic sciences.

See appendix table A-16.

[18] Japan's percentage is similar to the proportion of engineering degrees in Singapore, Korea, and Taiwan. Only China has a considerably higher concentration on engineering: 40 percent of Chinese undergraduates study engineering (NSF, 1993).

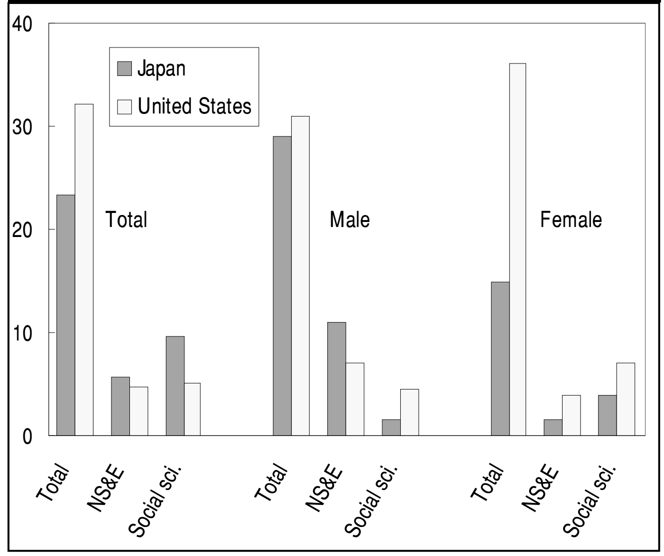
degrees is shown in figure 20 by adding computer science and engineering degrees in the U.S. data.[19] U.S. combined degrees in these fields grew rapidly from 1975–86, declined until 1991, and subsequently leveled off. The decline after 1986 is largely due to demographics and the apparent waning interest in computer science degrees at the undergraduate level. In the last decade, the number of Japan's degrees in computer science and engineering grew at an average annual rate of about 2 percent. By 1994, with roughly one-half the population, Japan produced more engineering and computer science degrees at the undergraduate level than the United States.

In contrast, relatively few degrees are earned in natural science departments in Japan, compared with the United States (even given that some degrees in applied science fields are counted within engineering). Only 3.5 percent of undergraduate degrees in Japan are earned in natural sciences (physical, environmental, and biological sciences), and even fewer, 2.9 percent, are obtained in agricultural sciences Monbusho, 1995b). In the United States, 9.3 percent of all undergraduate degrees are earned in the natural sciences, and 1.1 percent are earned in agricultural sciences (table A-16). This low percentage of earned degrees in the natural sciences reflects the relatively minimal role of Japanese universities in fundamental scientific discovery.

Because of significant taxonomy differences, only aggregated comparisons are made on the proportion of 22-year-olds with NS&E degrees, with differences by gender (figure 21). Ten percent of Japanese males of this age earn university degrees in a field of natural sciences or engineering; about one-tenth that amount, or 1 percent, of the Japanese female population, earn such degrees. In the United States, 6.8 percent of the male 22-year-old population earn a university degree in a field of natural sciences or engineering. About one-half that amount, or 3.6 percent, of the female population earn such degrees.

Japan and the United States have a similar concentration in particular engineering specialties at the undergraduate level, with some minor differences. The largest engineering departments in both countries are in electrical and computer engineering, as well as in mechanical, civil, and chemical engineering. Japan has a slightly higher concentration of students in chemical and civil engineering fields, and a slightly lower concentration of students in aeronautical and mechanical engineering fields than the United States (table 9).

Figure 21. First university degrees as a proportion of the 22-year-old population: 1994



KEY: NS&E = Natural sciences and engineering.

SOURCE: National Science Foundation/SRS; table A-17.

Table 9. First university engineering degrees by field of study: 1994

Field of study	Japan 1/		United States	
	[Number]	[Percent]	[Number]	[Percent]
Total	91,184	100.0%	63,012	100.0%
Aeronautical/astronautical	776	0.9	2,330	3.7
Chemical	10,335	11.3	5,636	8.9
Civil	18,015	19.8	10,603	16.8
Electrical and computer	27,346	30.0	18,241	28.9
Industrial	4,757	5.2	3,453	5.6
Mechanical	18,664	20.5	15,297	24.3
Materials/metallurgy	1,125	1.2	1,106	1.8
Other	10,166	11.1	6,346	10.1

1/ Computer science is included within engineering departments in Japan. See appendix table A-16.

SOURCES: National Science Foundation, SRS, *Science and Engineering Degrees 1966–94*, NSF 96-321 (Arlington, VA, 1996); and Monbusho, Basic Education Survey, 1995.

[19] Because the numbers associated with solid-state physics in Japan are so small, these degrees were not reclassified here.

Japanese national educational reforms at the undergraduate level are directed toward more teaching of core fundamentals and an integration with, and more equal status of, the faculties of general (first 2 years) and specialized (final 2 years) education. Within engineering, Japanese universities are combining several small engineering departments for a broader, multidisciplinary perspective. Japanese universities also are introducing undergraduate research programs similar to the undergraduate research opportunity programs in the United States.

At the graduate level, reforms are directed toward increasing the scale of programs, improving the substance by introducing more course work (similar to the U.S. system), diversifying funding sources (including joint research with industry), and enhancing mobility of scientists with fixed-term appointments (Arimoto, 1996).

Trends in Graduate Education

Graduate Enrollment

Graduate S&E programs, traditionally small in Japan, have begun to expand. To increase graduate enrollment in Japan, in the late 1980s, Monbusho began establishing new universities for graduate students only. The Japan Advanced Institute of Science and Technology, East (Ishikawa Prefecture), provides research and training in information science and materials science. The Advanced Institute of Science and Technology, Nara Prefecture, begun in 1991, focuses on research and training in information science as well as bioscience.

Since 1988, industry has been allowed to donate named grants for industry—university joint research. A few universities have taken the opportunity to pursue financial support and cooperative research with industry for innovative graduate training. For example, the Research Center for Advanced Science and Technology (RCAST), within the University of Tokyo, created four research divisions in 1988, admitting only doctoral candidates.

Based on these new graduate institutes and centers at universities, graduate student enrollment grew at an annual rate of 15 percent from 1990–95 (Monbusho, 1995b). Previously, only those going into academic careers remained in the university for doctoral training. Others had no financial incentive because starting salaries in industry were the same as for those hired at the bachelor's level (Yano, 1986). Presently, more students in Japan are going forward to earn advanced degrees in natural sciences and engineering. By 1994, the ratio of undergraduate-to-graduate enrollment in engineering was 8:1. In 1975, the ratio of undergraduate-to-graduate enrollment in this field had been 20:1 (table A-18).

In the United States, with significantly larger S&E graduate enrollment in higher education, the ratio of graduate-to-undergraduate enrollment in engineering was around 3:1 in 1994. Even with the recent expansion, in 1994 Japanese graduate enrollment in all S&E fields was 91,000 compared with 433,000 in U.S. universities. Particularly small are Japanese graduate programs in the natural sciences—about one-tenth the size of those of the United States (12,000 versus 120,000 graduate students) (table A-18). In contrast, in engineering Japan has comparable enrollment in graduate programs to the United States (relative to the size of its population). In the United States, after a decade-long steady increase, graduate enrollment in S&E fields at universities declined in 1994, mainly as a result of the decline in the number of foreign graduate students in engineering both in 1993 and again in 1994 (National Science Board, 1996).

One educational policy goal in Japan is to double the number of graduate students by the year 2000, that is, from approximately 138,000 graduate students in 1994 to 277,000 graduate students in the year 2000. Such doubling would require sustaining a 12-percent annual growth rate in the number of students entering advanced degree programs. From 1990–94, the annual rate of increase was around 12 percent. Doubling the number of graduate students appears possible if all the attractions to advanced degree programs in universities continued: increasing financial support to graduate students, more exciting research at universities, and availability of state-of-the-art facilities.

A large uncertainty for the continued expansion of graduate programs is when the long economic recession will end, and thus, enable Japanese industry to begin to hire those with advanced S&E degrees. Even without doubling the number by the year 2000, the rising participation rate in graduate-level programs will create a demand for more professors at this level. The decline in the college-age population will contribute to a shift in professors from undergraduate to graduate programs.

ADVANCED DEGREES

Since 1985, Japan's rate of growth in the number of degrees earned in natural sciences and engineering has been more than twice as high at the master's level than at the bachelor's level. Doctoral degrees began increasing a few years later (figure 22).

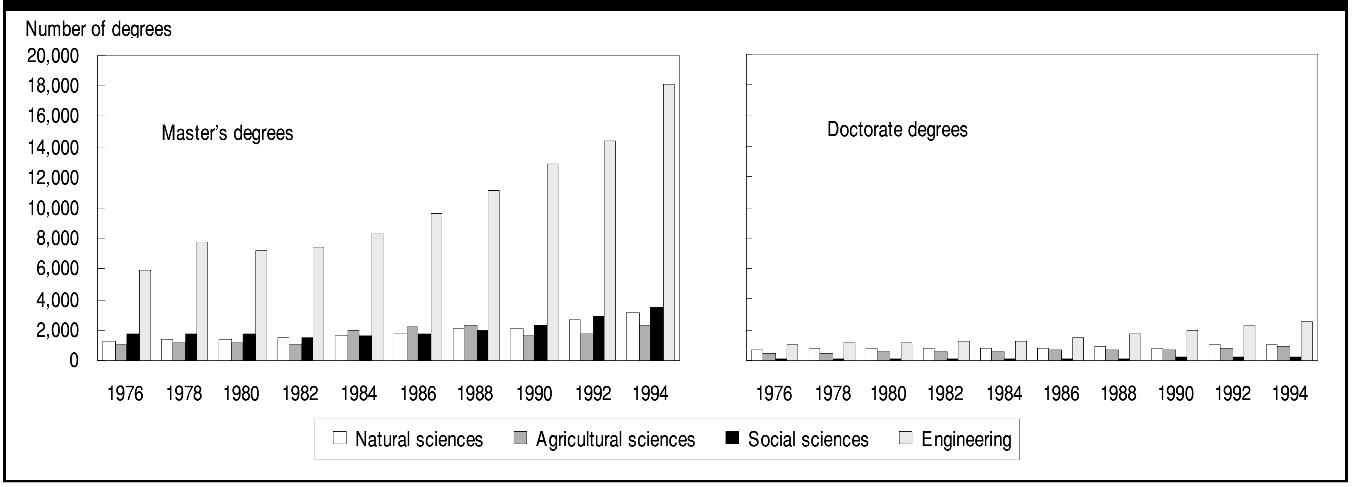
The number of graduate degrees in science and engineering is considerably larger in the United States than in Japan (figure 23).

From 1987–92, engineering doctoral degrees in Japan grew at the rate of 6.4 percent a year, and natural science doctoral degrees grew at the rate of almost 5 percent annually in the 1990s (figure 24).

Since this expansion is from a low base, however, the ratio of doctoral recipients to the general population is still relatively low in Japan. In 1994, 0.26 percent of the 29-year-old population had earned a doctoral degree in the natural sciences or engineering, compared with 0.50 percent of the same population in the United States[20] (table A-21).

Until recently, most doctorates in the natural sciences and engineering in Japan were earned by industrial researchers in Japanese companies. These degrees are awarded by the employees' former university, usually after many years of research in industrial laboratories. No matriculation is necessary, only submission of a dissertation. Until the 1990s, these doctorates, called thesis doctorates, or *ronbun hakase*, represented the majority of engineering doctoral degrees from national universities. In 1986, *ronbon hakase* represented two-thirds of all doctoral engineering degrees and more than 40 percent of all natural science degrees. With the expansion of university-based doctoral programs, however, the proportion of these degrees earned is decreasing. From 1986–94, doctoral degrees earned within Japanese universities increased 5 percent annually in the natural sciences[21] and 13 percent annually in engineering. Thesis doctorates in science and engineering grew at a much smaller rate during this same time period. By 1994, more doctoral engineering degrees were earned for research within university laboratories (53 percent) than industrial research laboratories (47 percent) (figure 25 and table A-20).

Figure 22. Graduate S&E degrees in Japan

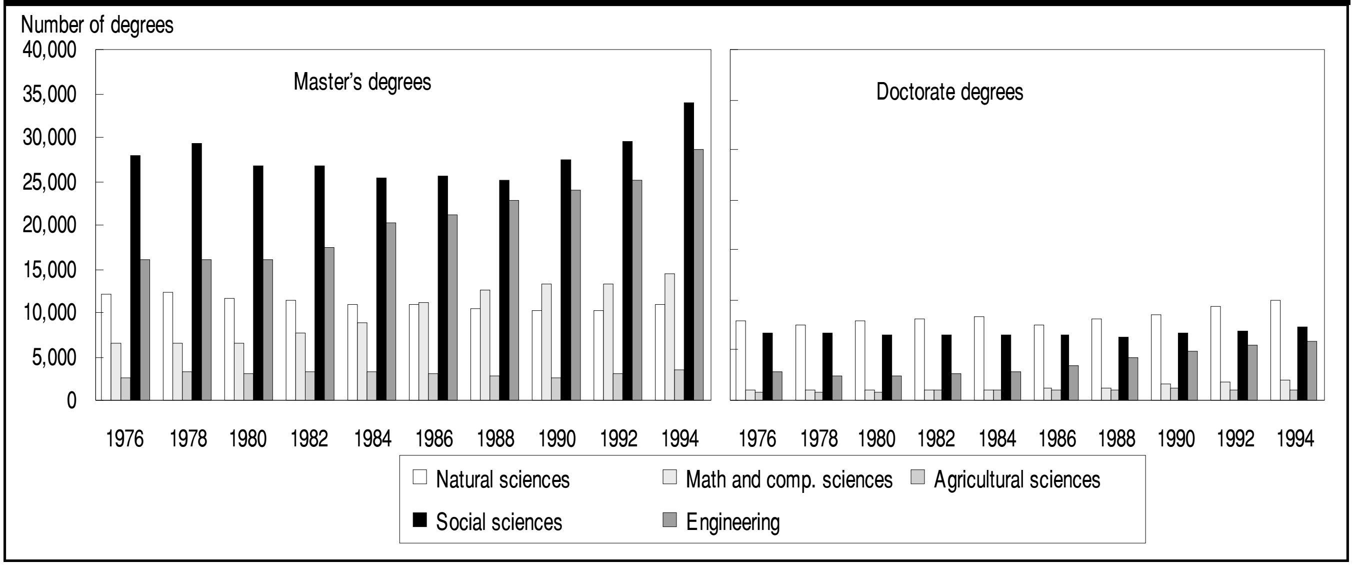


See appendix tables A-19 and A-20.

[20] Includes coursework doctorates, not *ronbun hakase*. The average age for these doctorates, earned by persons employed in industry, is 40-years-old for natural sciences and 42-years-old for engineering.

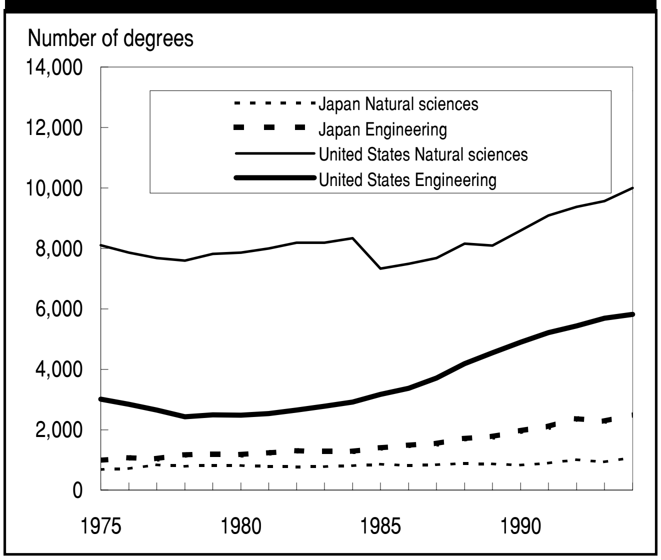
[21] Natural sciences include physical, biological, earth, atmospheric, and oceanographic sciences.

Figure 23. Graduate S&E degrees in United States



See appendix tables A-19 and A-20.

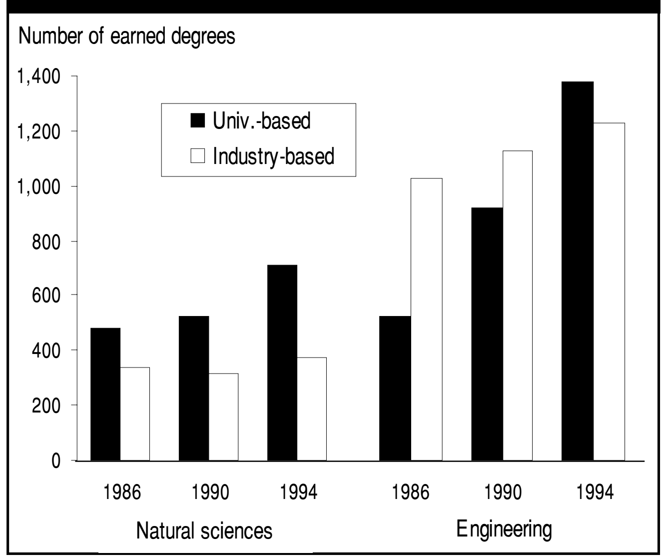
Figure 24. Doctoral degrees in NS&E fields: 1975–94



KEY: NS&E = Natural science and engineering.

See appendix table A-20.

Figure 25. Expansion of Japan's NS&E doctoral degrees



KEY: NS&E = Natural science and engineering.

See appendix table A-20.

Using the better equipped and funded industrial research laboratories for doctoral research training worked very well for Japan during the last several decades of technology development, and likely contributed to their economic success. Japan's technology policy from the 1950s to the 1970s was geared toward large funding of research by industry for adaptive borrowing and quality engineering (Tamura and Peck, 1983). Those familiar with Japan's educational system believe that it has been very well-suited to industrial catch-up, but may not be adequate for the future. Japan now wants to develop the human resources for science and engineering that can create radically new technologies, rather than just adapt and improve on imported technology. In addition, because of their high economic status in the world, international expectations are rising that Japan will apply more of its resources to the kinds of basic research that will have universal benefits (Rohlen, 1995).

A long-discussed shift is occurring toward stronger doctoral programs within university laboratories, with more funding for basic research. Public statements of the need for this shift have been made in Japan for at least the past 25 years. Japan's S&T White Papers since 1973 have emphasized the need to enhance government funding and university basic research to solve new problems that cannot be addressed by off-the-shelf technology (STA, 1973). Initially, these public statements did not change the research picture. Throughout the 1970s and 1980s, industrial research represented an ever-increasing proportion of research. While the amount of government funded research increased slightly, it continued to decline as a percentage of overall research because of the huge industrial research investment.

Financial Support to Graduate Students

Although no national comparative data are available on financial support to graduate students, recent studies show that Japan has traditionally provided little financial support for graduate students. The costs for graduate students in Japan's national universities include a $300 entrance exam, a $3,000 entrance fee, and a $4,500 tuition payment per year. About 26 percent of masters students and 59 percent of doctoral students receive "scholarships" (which are actually interest-free loans that have to be repaid after graduation). Japanese graduate programs provide no tuition waivers for students in science and engineering (Sienko, 1996). In contrast, 70 percent of S&E graduate students in U.S. universities are supported by research assistantships, teaching assistantships, fellowships, and traineeships from federal and university sources (NSB, 1996). Only 30 percent are self-supporting, mainly in the social sciences. In the United States, financial aid includes tuition waivers in a large majority of graduate programs.

Japan is beginning to provide financial aid to graduate students in the form of postgraduate fellowships and research assistantships. Monbusho funds provide assistance to Japanese students, to foreign students for study in Japan, and to Japanese students to study abroad. A small percentage of graduate students (6 percent) receive generous fellowships from the Japan Society for the Promotion of Science (JSPS), similar to the level of support students receive in U.S. graduate schools, to encourage students to proceed up to the doctorate level. New fellowships available in 1996 from JSPS have expanded funding to 1,350 new postdoctorates and doctoral students and have provided 1,750 continuing awards from the previous year. By 1996, about 6,000 Japanese graduate students and postdoctorates had some government funds. The target is to fund about 10,000 government fellowships (JSPS, JST, and NEDO) by the year 2000.

In contrast, in the United States, in 1993, 45,000 graduate students received their primary support from fellowships and traineeships, and another 155,000 were supported primarily through research assistantships and teaching assistantships (NSB, 1996).

Foreign Students in Graduate Programs

The majority of foreign students in Japan are at the undergraduate level. Only 17,800 out of 50,000 foreign students are studying at the graduate level. In contrast, in the United States, almost one-half of the 425,000 foreign students are studying at the graduate level. Of the approximately 191,800 who come to the United States for graduate studies, about one-half are in the natural sciences and engineering fields. Likewise, more than one-half of the foreign graduate students in Japan are in S&E fields (table 10).

Table 10. Foreign students in S&E graduate programs: 1994

Field of study	Japan		United States	
	[Number]	[Percent]	[Number]	[Percent]
Total	17,801	100.0%	191,798	100.0%
S&E fields	10,127	56.9	96,475	50.3
Natural sciences	852	4.8	29,153	15.2
Agricultural sciences	1,559	8.8	5,562	2.9
Social Sciences	2,967	16.7	17,645	9.2
Engineering	4,749	26.7	44,114	23.0
Other fields	7,674	43.1	95,324	49.7

SOURCES: Government of Japan, Monbusho, unpublished tabulations; Institute of International Education, *Open Doors, 1994–95* (IIE: New York, 1995), and unpublished tabulations.

Among the leading countries of origin of foreign graduate students in Japan are China and Korea, comprising almost three-quarters of the 17,800 foreign graduate students present in 1994. Most other leading countries of origin also are within the Asian region. The leading countries of origin of foreign graduate students in the United States are China and India, comprising one-third of the total foreign graduate students present (table 11).

Table 11. Leading countries of origin of foreign students in graduate programs: 1994

Country of origin	Japan		United States	
	[Number]	[Percent]	[Number]	[Percent]
Total	17,801	100.0%	191,738	100.0%
China	9,152	51.4	36,370	19.0
Korea	4,003	22.5	27,553	14.4
Indonesia	642	3.6	24,623	12.8
Bangladesh	461	2.6	15,785	8.2
Thailand	460	2.6	7,755	4.0
Other	3,083	17.3	79,652	41.5

SOURCES: Government of Japan, Monbusho, unpublished tabulations; Institute of International Education, *Open Doors, 1994–95* (IIE: New York, 1995), and unpublished tabulations.

Foreign students comprise only 8 percent of the total graduate enrollment in the natural sciences in Japanese universities, and they account for only 10 percent of the engineering students. They are concentrated at the doctoral level, however, and are contributing to the expansion of doctoral programs and degrees in Japanese universities. In 1992, 37% of the engineering doctoral degrees were earned by foreign students; 25% of the natural science doctoral degrees were earned by foreign students in the same year. In contrast, in U.S. universities, slightly more than 50 percent of the engineering doctoral degrees and one-third of the natural science doctoral degrees were earned by foreign students in 1993.

Foreign doctoral recipients have increased at the annual rate of 13 percent from 1987–92. For this number to double, from approximately 1,000 in 1992 to 2,000 in the year 2000, would require sustaining an annual growth rate of 12 percent. This would be possible, but only likely if financial support to foreign doctoral students also continued to increase.

Graduate students from the United States account for only 1 percent of the foreign graduate students in Japan, and relatively few of them are in S&E programs requiring university research laboratories. A few dozen American graduate students are studying for their master's degrees in engineering within Japanese universities while only a few Americans are studying natural sciences within Japanese universities. In contrast, Japan is one of the leading countries of origin for foreign students and foreign researchers in U.S. universities and also for visiting scientists at U.S. laboratories. In 1993–94, the numbers of students and researchers from Japan reached almost 50,000. About 40,000 are students, and 10,000 are conducting research (table 12).

Table 12. Japanese foreign students and visiting researchers to the United States: 1993–94

Category	Number
Total	49,578
Students	39,715
Undergraduate	31,960
Graduate	7,755
Researchers	9,863
Post-doctorate/U.S. univ	4,055
Foreign scholars/U.S. univ	5,458
Visiting scientists/NIH 1/	350

1/ NIH has the largest visiting scientists program, but other U.S. government agencies also receive visiting scientists from Japan.

NOTE: Researchers are based mainly on estimates for post-doctorates and foreign scholars in *Open Doors, 1994–95.*

SOURCE: Institute of International Education, *Open Doors, 1994–95* (IIE: New York, 1996).

Of the Japanese foreign students coming to the United States, the large majority (80 percent) enter undergraduate programs for non-S&E fields of study. The most popular fields in which they major are business and economics. The attraction to U.S. higher education is partially attributable to stiff competition for admission to the prestigious Japanese national universities. Many Japanese students who do not pass the qualifying examinations for these top schools have opted for U.S. undergraduate education because the less-competitive Japanese private schools, their other option, are costly and crowded. Relatively few of the Japanese students in U.S. undergraduate programs (6 percent) study natural sciences or engineering.

A far smaller number of Japanese foreign students enter U.S. graduate programs, and only a small fraction of these study the fields of science and engineering. Traditionally, relatively few Japanese entered lengthy doctoral programs of science or engineering in U.S. universities. However, similar to the recent increase in S&E doctoral degrees within Japanese universities, the number of degrees earned by Japanese students in the U.S. universities is also increasing. In 1994, Japanese foreign students earned 46 doctoral degrees in engineering and 136 doctoral degrees in all fields of science, similar to the number earned by foreign students from other industrialized nations, such as Germany (NSF, 1996b).

Chapter 5. Academic R&D

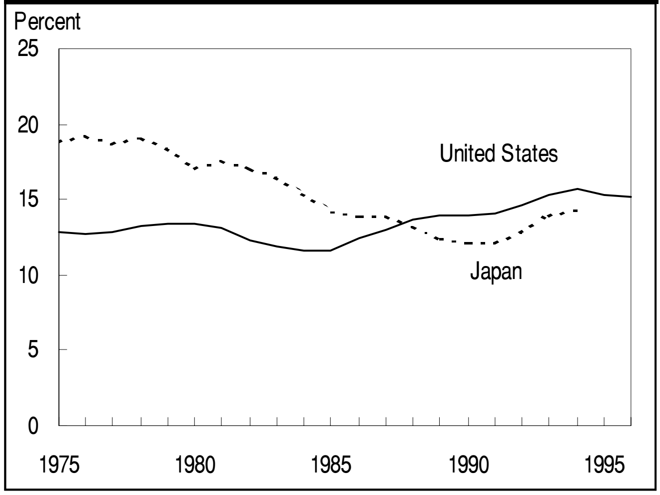
The problems of Japanese universities, as well as their proposed solutions, have been widely noted and discussed.[22] Solutions revolve around ways to increase the quality of research performed in universities: providing competitive funding to university professors and more financial support to graduate students, and improving facilities and equipment in graduate departments. The Science and Technology Basic Plan especially focuses on removing the barriers to high-quality basic research in universities and national laboratories. The Japanese government plans to systematically improve the research facilities and instrumentation of national universities, and also the computer networks among R&D institutions. With these changes, their conduct of science will resemble more closely that of the United States: more government funding of basic research, more competitive research grants, more centers of excellence in universities, and expanded graduate programs, postdoctorate fellowships, and research assistantships.

The Japanese government also plans to promote and fund joint research between industry, university, and government laboratories. Government laboratories will hire additional S&E personnel on fixed-term appointments and, based on expected reforms in the National Personnel Authority, there will be more flexibility for universities in hiring faculty and researchers. Monbusho is planning to submit a bill to introduce a limited tenure system at the nation's colleges and universities during an ordinary Diet session early in 1997.

Academic R&D Trends

The decade-long trend, observed from 1980–91, toward a diminishing role for academic performers in total Japanese research and development, ended in 1992. During that period, academic performance decreased from a 17-percent share to a 12-percent share of total Japanese R&D performance (figure 26).

Figure 26. Higher education R&D expenditures as a share of total R&D



See appendix tables A-2 and A-5.

As a result of strong support provided by the government's 1993 and 1994 budgets, Japan's academic performance rose to a 14-percent share of total Japanese R&D. Although this is partly due to a decline in industrial research, it is also due to the large government budgets (with supplemental budgets in 1993, 1995, and 1996), which began the process of strengthening basic science in Japanese universities. It is expected that the previous diminishing trend will reverse, and that academic R&D will continue to increase as a share of the national performance total in the next several years.

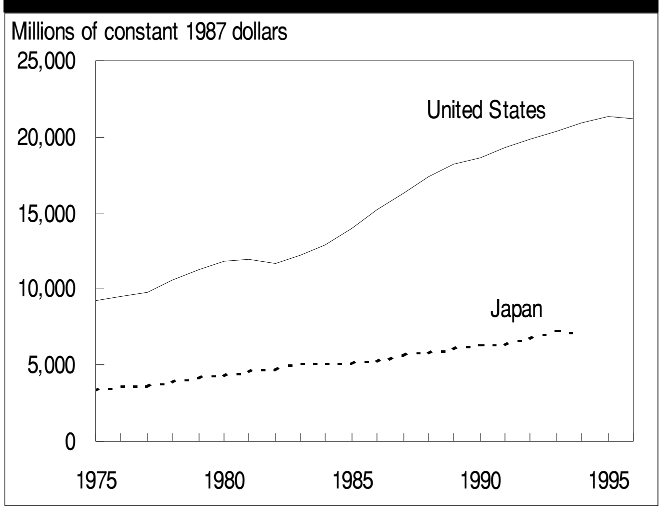
Approximately 30 Japanese universities are strong in scientific research, as well as education (Arima, 1992). There are 63 attached research institutes within these universities, 18 of them for joint use. In the 1970s, Monbusho began building National Inter-University Research Institutes that are open to all university researchers. They provide large-scale, well-equipped research facilities that also serve for international collaboration in specific fields. The first of these inter-university research institutes was the National Laboratory for Higher Energy Physics, KEK. These institutes, now numbering 15, have the same status as national universities. The Graduate University for Advanced Studies (GUAS), established in 1988, is also for graduate students working in these same institutes (Monbusho, 1995).

[22] See, for example, the Japanese National University Association "Basic Research on University Operations," 1992, which surveyed all national university professors on their research environment and made recommendations to Monbusho on how to improve the present status. American Association for the Advancement of Science (AAAS). 1992. *Science in Japan. Science* 258, 23 October. Special issue on Japan.

While research flourished in the 1970s, the government's deep cuts in university construction budgets and general funds for basic research in the 1980s seriously affected Japanese universities' ability to do research. The retrenchment of government research in the 1980s forced universities to look to industry for donations and small additional sources of support. Until multiple funding sources became possible in 1995, the funding of these national universities had been centralized through Monbusho. Professors are civil servants and all faculty (both senior and junior) are tenured for life.

Based on several science advisory reports such as that conducted by the Japanese National University Association (see *"Japan's University Survey*"), an important Cabinet document formulated a science policy that recognized the importance of basic research for Japan and proposed improvements in research conditions. The 1992 S&T policy document included a major renewal of facilities and equipment for universities and national research institutes, and expanded competitive research grants. The Japanese government made large supplemental budgets to Monbusho in 1993 and 1995 to begin to address these recommendations. The latest available data on R&D expenditures in the higher education sector show academic R&D reached approximately $7 billion in 1994. In that same year, U.S. academic research reached $21 billion (figure 27).

Figure 27. R&D expenditures in the higher education sector



See appendix table A-5.

The distribution of higher education R&D expenditures by field differs across countries. Japanese priorities for academic research in 1993, as indicated by dollar amounts of research funded, were medicine, social sciences, and engineering, in that order. In contrast, in the United States, academic research is focused on the natural sciences. Research in fields of natural sciences reached 35 percent of overall U.S. university research in 1993, an amount that is almost equal to that performed in both medicine and engineering combined (figure 28).

Academic research in public universities is primarily supported by formula funding, but mechanisms for industry—university cooperative research were introduced in the 1980s. Funds for scientific research are provided by Monbusho to university "chairs" based on the number of researchers and graduate students. In addition, in 1983 Monbusho allowed university professors to participate in industry—university projects (ERATO) funded by the Science and Technology Agency (STA). Under ERATO, a new facility is established with 5-year funding for joint projects by industry and university professors. ERATO differs from the U.S. National Science Foundation's S&T Centers in that professors under ERATO funding are hired away from their university, and project equipment does not build on their current university laboratory.

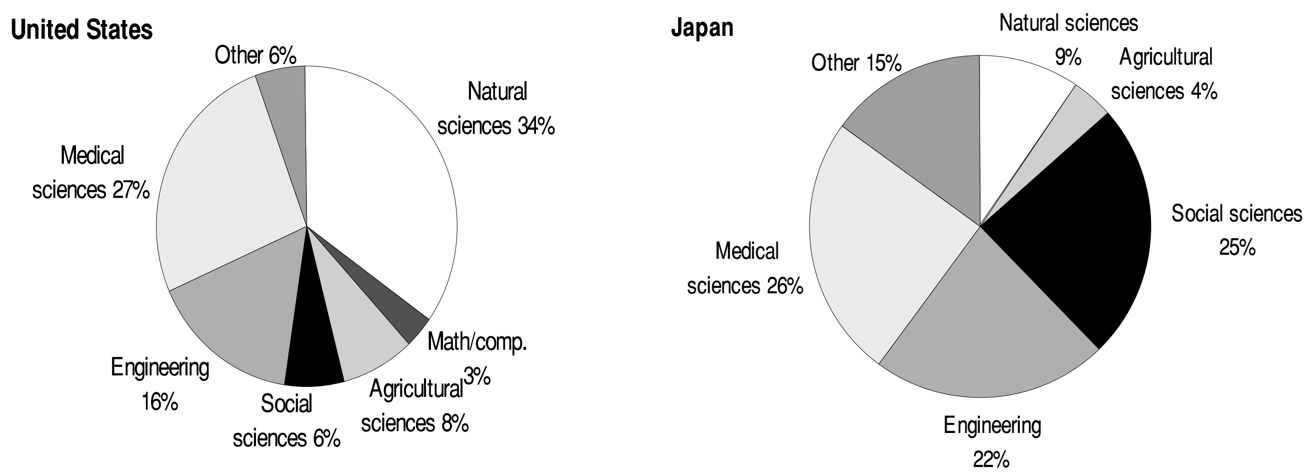
In the 1990s, Japan's university research funding is increasing through Monbusho's additional funding of grants-in-aid and from a trend toward multi-channel funding. After 1995, government agencies other than Monbusho can contribute directly to academic science. Monbusho has recently written legislation to allow direct funding of university researchers by STA and MITI. Monbusho also increased funding for competitive research to 100 billion yen in 1996 (approximately $450 million dollars) (Monbusho, 1996). These research funds are provided to individual researchers on the merit of their proposals through Monbusho's Grants-in-Aid Division.[23] Considering sources of funding from various science agencies, competitive research support reached almost $875 million (in constant 1987 million dollars) at national universities by 1995 (table 6). The overlapping funding of universities by other government agencies (STA and MITI), which is now permitted, provided one-quarter of a million dollars to national university research funding in that same year; industry almost $200 million dollars.

[23] See NSF Tokyo Report 95-18 (NSF, 1995a).

Japan's University Survey

In 1992, the Japanese National University Association conducted a survey of all national university professors regarding university operations and their research environment. The survey included items on their salary, equipment, space, barriers to the pursuit of research, teaching hours, travel and research grant funds, and any cooperative activity with industry. The survey also solicited their opinion of the quality of their research, whether funds other than Monbusho would be good for national universities, whether shared use was possible for their equipment needs, and how to improve the present status of university research. Of the respondents from national universities, 60 percent considered their conditions "very much inferior" to those in the industrial sector (Koizumi,1993). The results were summarized and recommendations were made to Monbusho to improve research equipment and its efficient use by opening facilities to other universities, to increase the budget for research grants and travel, to introduce funds from other organizations into the university, and to strengthen its linkages with other ministries (STA and MITI) involved in funding Japanese science.

Figure 28. Distribution of higher education expenditures, by field: 1993



See appendix table A-22.

The majority of university research funding, however, still comes from Monbusho's formula funding of university chairs.

These three ministries (Monbusho, STA, and MITI) also came together to provide multiple funding sources for the creation of university Centers of Excellence (COE). (See NSF Tokyo Report 95-22 for background on Monbusho and STA programs for COE, NSF, 1995b). The objectives of these centers are to be the focal point of information in a particular field, set a research direction that is leading the field, and have a significant output of research articles in that field. While Japanese industry will continue to use U.S. graduate schools for advanced training of their researchers, Japanese industry will likely expand their collaboration with Japanese universities' emerging centers of excellence.

In 1996, Monbusho has provided JSPS with new competitive research funds for all universities. Similarly, STA initiated new programs in 1995 to which researchers in universities and national laboratories affiliated with STA may apply. MITI has done the same. The problem of lack of technicians in university research laboratories is addressed in these new funding schemes, which allow hiring of needed technicians for a fixed-time research project.

Government Financing of Research Facilities

Japan's government is supporting cutting-edge facilities under Monbusho and STA funding, and is a contributing member of CERN for international cost-sharing. (AAAS, 1997). The major focus is on renovation of existing facilities and on new national inter-university research institutes that allow shared-use by several universities. Monbusho's support of new world class facilities and "big science" allows for the expansion of basic science in the fields of astronomy, high-energy physics, space science, environmental earth, and bioscience. (See *"Japan's Unique Scientific Facilities"* on increased opportunities for access by the international research community to these unique scientific facilities.)

Japan's Unique Scientific Facilities

Japanese government agencies (STA and Monbusho) have growing science budgets to provide a boost to the funding and realization of world class research facilities, such as The International Thermonuclear Experimental Reactor (ITER). The goal of this facility, funded by the Russian Federation, Europe, the United States, and Japan, is to demonstrate controlled ignition of plasmas and, ultimately, the utilization of fusion power for practical purposes. Japanese funding is especially encouraging because of tight European and U.S. science budgets for international facilities. For example, Japan's 1997 government budget authorized $32 million for their role in planning the Large Hadron Collider (LHC) at CERN in Switzerland (AAAS, 1997). In addition, Japan's recently launched MUSES-B satellite will provide radio astronomers the first space-based antenna dedicated to very long baseline interferometry (Normile, 1997); multinational collaborators will take the radio-astronomical observations. Japan's proposed facility in radio astronomy, called Large Millimeter and Submillimeter Array, is expected to provide one of the dominant facilities in millimeter-wave astronomy for the first quarter of the next century (Mervis, 1997).

Japan's increased government science budget will also contribute to large international research projects, such as the Ocean Drilling Program (ODP) and the continuation of the Human Frontier Science Program, providing funding to U.S. and European researchers. Japan has the first full-scale neutrino astrophysical observatory in the world, with 30 American collaborators. The SPring 8 synchrotron radiation facility under construction in Kobe will be completed in 1998 and open to overseas researchers.

Astronomical research will be strengthened through the Nobyeama Cosmic Radio Observatory and the Subaru facility in Hawaii, providing the largest single-mirror optical telescope (an 8-meter diameter optical and infrared telescope), open to the world's research community. Monbusho's support of the so-called "Super-Kamiokande" facility at the Institute for Cosmic Ray Research of the University of Tokyo, will allow unique solar and atmospheric neutrino experiments. Accelerator research will benefit from a new particle accelerator facility, called the KEK B-Project, will explore asymmetrical behavior among particles and antiparticles. The National Institute for Fusion Science will complete the Large Helical Device Facility to study steady-state plasmas leading to a fusion reactor (AAAS, 1997).

Chapter 6. Outputs of R&D

While it is difficult to accurately measure the returns to a nation's R&D investment, new knowledge resulting from R&D is sometimes identifiable by discrete events, which can be used as measures of the *output* of R&D activity. Bibliometrics (scientific publications and their citation by other researchers) and patents are two such *output* indicators. Scientific publications reflect research of significance to the scholarly community while patent registrations reflect inventive activity of potential commercial consequence.

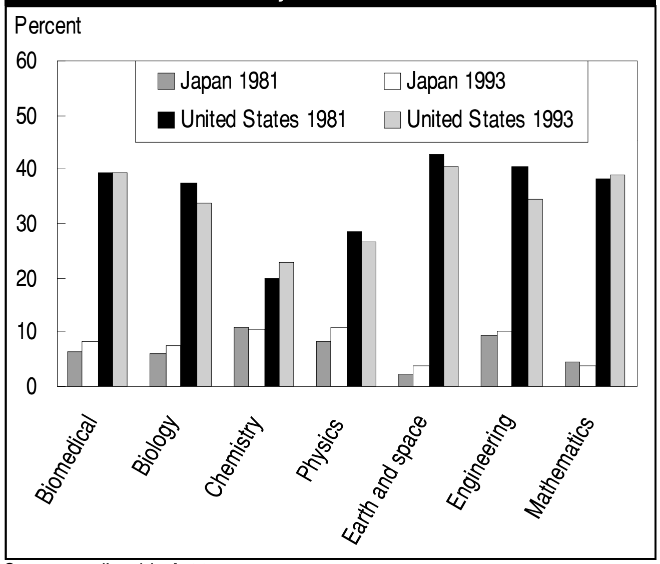
The *impact* of new knowledge resulting from R&D is even more difficult to measure, especially with regard to basic research. R&D would, however, be expected to have an impact on such economic factors as productivity, demand for technological know-how, and international trade. These factors are, in turn, quantifiable in the form of manufacturing output, royalties and fees paid to firms to gain access to technological know-how, and trade surpluses from trade in advanced technology products. These can be used as rough measures of the impact of a nation's R&D efforts.

Scientific Literature

The database used here to compare U.S. and Japanese scientific literature consists of scientific and engineering articles published in the set of 4,681 natural science and engineering journals covered by the Institute of Science Information's (ISI) Science Citation Index (SCI).[24] SCI covers major refereed scientific and technical (S&T) journals from around the world (NSB, 1996). This database is biased toward the English language so it does not reflect all of Japan's S&T literature. Rather, it is reflective of Japan's proportion of articles in this set of globally influential S&T journals.

Japan's share of the world's scientific and technical articles increased somewhat from 6.6 percent in 1981 to 8.8 percent in 1993, based on larger shares of publications across several fields, including clinical medicine, biomedical research, biology, physics, and engineering. Only in chemistry and mathematics has Japan's share of the world's scientific articles decreased from 1981–93 (figure 29). Japanese research papers in material science, agriculture, and astrophysics are frequently cited by other researchers—a clear indication of the quality of Japan's research in these fields (NISTEP, 1995).

Figure 29. Share of world's scientific articles, by field: 1993



See appendix table A-23.

In contrast, as other countries have increased their production of scientific publications, the U.S. share of the world's scientific articles has decreased from 35.9 percent in 1981 to 33.6 percent in 1993. As scientific knowledge is diffused throughout the world and civilian research budgets in the European and Asian regions are becoming comparable to that of the United States (each region reached $100 billion in 1992), a greater share of the world's scientific literature originates in laboratories outside the United States (NSF, 1993 and NSF, 1996c).

[24] The database encompasses the natural sciences and engineering. The social and behavioral sciences tend to rely more on publication vehicles not covered by ISI (e.g., books and monographs). For this reason, these fields are omitted from the database. The database also excludes letters to the editor, news pieces, editorials, and other content whose central purpose is not the presentation or discussion of scientific data, theory, methods, apparatus, or experiments. ISI periodically updates its journal coverage, based in part on references in covered publications to others not yet included. Given this citation-based updating, one can conclude that ISI provides reasonably good coverage of a core set of scientific journals (albeit with some English language bias), but not necessarily of all that my be of local or regional importance.

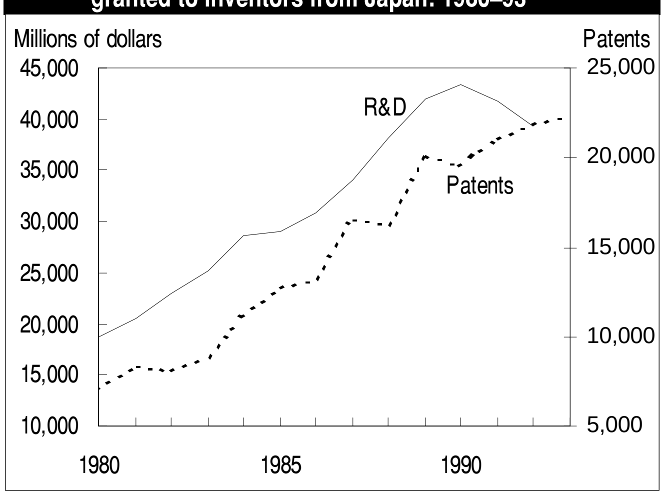
Japan's goal of increasing its international cooperative research, as stated in S&T White Papers since the mid-1980s, has resulted in increased international coauthorship. In the 1988–93 period, almost 11 percent of Japan's scientific articles in this set of journals were internationally coauthored, up from 7 percent in the previous period of 1981–87. While U.S. scientists are still the main collaborators on internationally coauthored articles with Japanese scientists (43 percent), an increasing percentage of these articles are based on collaborations with scientists from European (34 percent) and Pacific Rim (14 percent) countries, particularly China (NSB, 1996).

PATENTS

Patents are one output indicator, albeit partial and imperfect, of the growth in new products and processes that result from industrial R&D. U.S. patents can be viewed as an indicator of global patenting. The analysis of U.S. patenting activity which follows has the advantage of comparing patenting across countries within a patent system requiring the same criterion of invention for patent application.

Japan's investment in industrially funded R&D mirrors the number of U.S. patents granted to Japanese inventors over the last 13 years. (See figure 30.) The very strong growth in industrial R&D throughout the 1980s corresponds with similar strong increases in the number of patents during the same period. From 1980–90, the number of U.S. patents granted to Japanese scientists and engineers increased at an average annual rate of 10.6 percent, from 7,000 in 1980 to 19,524 in 1990. As Japanese industrial R&D funding declined in the early 1990s, the growth rate of the number of U.S. patents also declined, to 2.9 percent annually. Despite this recent slowing in patent growth rate, Japanese inventors still received about 23 percent of all U.S. patents in 1993 and represented almost one-half of all foreign patents granted in the United States, indicating a strong level of inventiveness (NSB, 1996).

Figure 30. Industrially funded R&D and U.S. patents granted to inventors from Japan: 1980–93



See appendix tables A-10 and A-24.

Japanese patenting activity in the United States has been particularly strong in the fields of computers, radio and television, electrical components and communications equipment, and motor vehicles and equipment. In each of these areas, the number of patents granted to Japanese inventors within the U.S. patent system has exceeded the number granted to inventors from all the countries of the European Economic Community (EEC) combined (NSB, 1996). By 1993, several Japanese firms were among the 10 top patenting corporations in the United States (table 13).

Table 13. Top patenting corporations: 1993

Company	Number of patents
IBM Corporation	1,085
Toshiba Corporation	1,040
Canon Kabushiki Kaisha	1,038
Eastman Kodak Company	1,007
General Electric Corporation	932
Mitsubishi Denki Kabushiki Kaisha	926
Hitaschi, Ltd	912
Motorola Incorporated	729
Matsushita Electric Industrial Company, Ltd.	713
Fuji Photo Film Coi, Ltd.	632

SOURCE: National Science Board, *Science and Engineering Indicators: 1996* (Washington, D.C.: U.S. Government Printing Office, 1996).

An examination of domestic patenting trends in Japan also shows the surge of applications from industrial researchers in the 1980s and a leveling off in the number of applications in the 1990s. In 1993, applications from Japanese inventors to the Japan Patent Agency declined (NISTEP, 1995). The number of patents granted to U.S. inventors also grew throughout the 1980s, at 2.4 percent annually, and even more slowly in the 1990s, at 2.0 percent annually.

Industrial Productivity

Recent assessments of Japanese technology have observed that one of Japan's strengths has been in applying technology to production processes. In industrial manufacturing fields that involve both complex products and processes, Japan excels and achieves a large international trade surplus (Kash, 1996). Japan has also made rapid progress in manufacturing productivity during the past decade; manufacturing output per worker-hour increased 4.3 percent annually from 1984–94, compared with a 2.9-percent annual increase in the United States in the same period (table A-25).

Table 14. U.S. receipts of royalties and license fees from Japan: various years 1/

Factor	1987	1990	1993
	[Millions of current dollars]		
Receipts	$723	$1,028	$1,392
Payments	88	141	194
Balance	635	887	1,198
Ratio of receipts to payments	8:1	7:1	7:1

1/ Generated from the exchange and use of industrial processes with unaffiliated foreign residents.

SOURCE: National Science Board, *Science and Engineering Indicators: 1996* (Washington, D.C.: U.S. Government Printing Office, 1996).

Royalties and Fees

Japan has traditionally been a net importer of technological know-how. In 1990, Japan paid over $7 billion in royalties and fees for access to intellectual property from other countries, more than twice as much as it sold to other countries. The United States has traditionally been a net exporter of intellectual property, maintaining a large surplus in international trade of technical knowledge. In 1990, the United States had more than a 3-to-1 ratio of receipts (exports) to payments (imports) for intellectual property. The surplus of receipts (sales of technical know-how) over payments (purchases) may indicate that the United States is strong in the creation of industrial technology (table A-26).

The amount of U.S. receipts of royalties and license fees generated from the exchange of industrial processes differs by country. Compared with the other major industrialized countries, Japan has the highest ratio of payments-to-receipts for access to U.S. technology. In 1993, U.S. companies received 7 times more than they paid in the exchange of technical know-how with Japanese firms (table 14).

However, when data from Japanese manufacturing industries are examined, a somewhat different picture emerges. In selected industries, Japanese companies are net exporters of technical know-how to the rest of the world. Data for 1990 show Japanese manufacturing industries' trade in technological know-how nearly in balance in 1990, and by 1993, Japanese companies received more in royalties and fees than they paid for technical know-how in several industry fields, including industrial chemicals, ceramics, iron and steel, and fabricated metals. Additionally, in motor vehicles the ratio of receipts-to-payments was 14-to-1, reflecting the spread of Japanese know-how in auto manufacturing in Europe and Asia (table A-27).

Trade in Advanced Technology Products

R&D and technological innovation play a major role in trade performance, particularly in advanced technology products.[25] The United States is the leading exporter of advanced technology products throughout the world, but has a large trade imbalance with Japan in these products. In 1992, the overall U.S. share of the world's exports of advanced technologies to all countries was about 25 percent, compared with Japan's share of 17 percent (table 15). The U.S. share of the world's exports is particularly large in biotechnology fields, aerospace industries, and weapons technologies, accounting for more than one-third of the world exports in these fields; Japan is particularly strong in information technologies and electronics, accounting for about one-quarter of the world exports in these fields.

[25] The list of advanced technology products is compiled by the U.S. Bureau of the Census. To be included in one of the categories, a product must contain a significant amount of one of the leading-edge technologies, and the technology must account for a significant portion of the product's value.

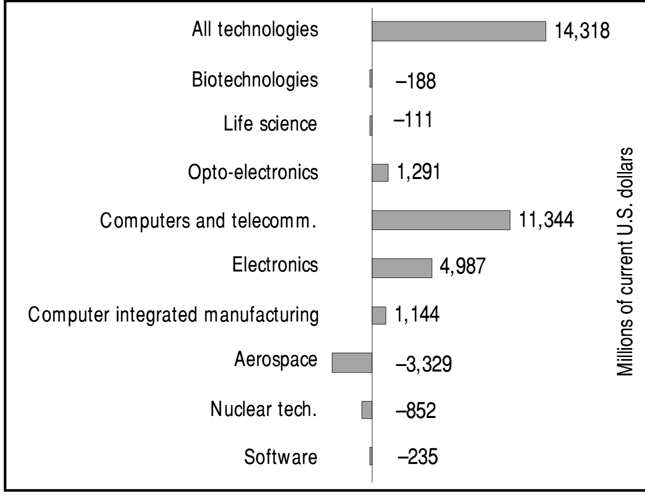
Table 15. Share of world exports of advanced technology products: 1992

Technology	United States	Japan
	[Percent]	
All technologies	25.2%	17.0%
Biotechnologies	37.0	4.3
Life science technologies	27.5	13.8
Opto-electronics	13.7	22.8
Information technologies	18.5	23.0
Electronics	20.3	25.5
Manufacturing technologies	16.2	21.5
Advanced materials	28.6	9.3
Aerospace	44.2	1.4
Weapons technologies	34.3	4.6
Nuclear technologies	20.8	0.2

NOTE: Technologies represent broader categories than the standard classification of industries.

SOURCE: DRI/McGraw Hill, special tabulations, April, 1994, as presented in *Science and Engineering Indicators: 1996.*

Figure 31. Japanese trade balance with the United States in advanced technology products: 1994



NOTE: Currency conversion uses official exchange rate.

See appendix table A-28.

However, in considering only U.S.–Japan bilateral trade (rather than world-wide trade), in 1994 Japan's export of advanced technology products reached more than $28 billion, exceeding imports from the United States by more than $14 billion and indicating that Japan is also strong in the creation of such industrial output. The largest trade surpluses for Japan are from computers and telecommunications and electronics. The largest deficits for Japan from high technology trade with the United States result from aerospace and nuclear technology, and increasingly from software (figure 31).

CHAPTER 7. SUMMARY

The trends presented in this report show that Japan has caught up with, or surpassed, the United States in some leading indicators of scientific and technological strength, and lags behind in others. Japan leads the United States in the percent of GDP invested in total and non-defense R&D, as well as government investments in civilian R&D as a percent of GDP. Japan is particularly strong in technology and trade indicators, and has a higher proportion of engineers in its labor force than the United States. Japan is still behind the United States, however, in R&D expenditures in higher education, in competitive research funding in universities, and in its share of the world's scientific articles. Japan has far smaller graduate S&E programs than the United States, especially in natural sciences. The research productivity of these departments is influenced by the number of qualified doctoral students, as well as the quality of professors (Ushiogi, 1993). Japan is attempting to address these weaknesses by increasing government science budgets targeted specifically for universities and national laboratories, with expansion of both doctoral programs and the national capacity for basic research.

IMPLICATIONS

Barring a major economic setback or other unforeseen situation, it appears that Japan can double government R&D support by the year 2000, or shortly thereafter. This suggests a stronger human and physical infrastructure for basic science in Japan and continued support by Japan for major international science programs. The overall result could be a continuing increase in the Japanese contribution to advancing science and engineering knowledge.

The current S&T strengths of Japan, coupled with their concerted efforts to advance their capacity for breakthrough research, have implications for their domestic science as well as global S&T. Some of these implications relate to issues in human resources for science and technology, higher education, collaborative research and science funding.

HUMAN RESOURCES

The additional funding is aimed at strengthening Japan's human and physical infrastructure for basic science. Domestically, Japan will continue expansion of doctoral programs and attempt to create centers of excellence in research. Until recently, most doctorates in the natural sciences and engineering in Japan were earned by industrial researchers in Japanese companies. By 1994, more doctoral engineering degrees were earned for research within university laboratories (53 percent) than for those in industrial research laboratories (47 percent). The planned funding of 10,000 fellowships for doctoral students and postdoctorates by the year 2000 would continue this trend.

The main Japanese science funding agencies are increasing the amount of competitive research funding to improve university research environments, and to overcome the deficiencies in present facilities and research personnel. New funding programs will facilitate collaboration of scientists from industry, universities and national laboratories, and provide for employment of research assistants and laboratory technicians on fixed-term projects (3–5 years). About 5–7 strong research institutes will receive large 5-year science funding to become centers of excellence, that is, research centers for world-class research in a particular field.

HIGHER EDUCATION

Japan is expanding funding and programs for U.S. and other international students to study in graduate programs in science and engineering in Japan. However, U.S. students have not taken advantage of ongoing educational exchange programs with Japan. One issue for the United States to address is whether or not interest can be mobilized among graduate and undergraduate S&E students for greater transnational competence.

INTERNATIONAL COLLABORATIVE RESEARCH

Japanese science agencies have growing R&D budgets to provide a boost to the funding and realization of world class research facilities, within Japan and abroad. For example, accelerator research will benefit from a new particle accelerator facility being built at the National Laboratory for High Energy Physics in Tsukuba Science City. The facility, called the KEK

B-Project, will explore asymmetrical behavior among particles and antiparticles. In addition, the SPring 8 synchrotron radiation facility under construction in Kobe will be completed in 1998 and open to overseas researchers.

The increase in government sponsored research in Japan, at a time when the United States and Western European governments have constrained science budgets, creates several opportunities for the international research community. Japan is providing additional funds to intensify international research cooperation on global issues, such as food, energy, environment and infectious diseases, and in basic sciences, such as the Human Frontiers and Human Genome Project. Japan is establishing international centers for R&D in Tsukuba Science City, and expanding both postdoctorate fellowships for foreign researchers and accommodations for foreign scientists at national laboratories.

This expanded government R&D funding and increased access to unique facilities suggest that issues concerning research cooperation for enhancing the advancement of basic knowledge and quickening the pace of scientific discovery, as well as ways for improving information about the scientific and technological accomplishments of Japan, could grow in importance in the near future. New issues are likely to arise concerning the best ways to enhance awareness and intensify U.S. involvement and cooperation with scientists and engineers in excellent facilities and research centers in Japan. For example, how might information flows be improved for the U.S. science community to identify promising candidates for further cooperation that would benefit both parties?

Science Funding and Accountability

Japan's decisions to double the government budget for R&D provides the United States and European countries an example of a different strategy in national science policy when facing difficult times. Like the United States and many European countries, Japan has a large national debt, a public eager to balance the national budget, and a private sector interested in keeping the government small. The prolonged economic recession in Japan has resulted in slower growth rates in its economy in the 1990s than in any other industrial nation. Nonetheless, Japan has chosen to protect and increase government funding of science as an investment in the future.

The additional funding, however, is made with high expectations for future benefits to society, and with requirements to evaluate the effectiveness of large public outlays. The rationale for increased funding of strategic basic research is its importance in recovery from recession and for its contribution to long-term sustainable development of Japan. It is expected that large funding of research projects with industry—university collaboration will lead to technological innovations, creation of new industries and a more prosperous society. Thus the Science Council is required to develop guidelines for an evaluation system of outcomes of large funding projects. This raises the issue of how the United States might best track the Japanese experience as an input to the development of government performance and evaluation measures in the areas of science and technology.

Need for Further Research

The Asian region is the fastest growing region of the world, with large potential markets for trade. While there is uneven growth among Asian countries, and uneven growth within large countries such as China, the combined economies of 12 countries in the Asian region were over $10 trillion in constant dollar terms in 1994 (table 16). Several countries within this region

Table 16. GDP of selected Asian countries: 1994

Country	GDP
	[Millions of constant 1987 dollars 1/]
Total	$10,367,511
China	4,353,706
Hong Kong	96,238
India	863,002
Indonesia	532,986
Japan	2,052,499
Malaysia	132,059
Pakistan	53,339
Philippines	1,363,716
Singapore	43,504
South Korea	371,644
Taiwan	194,452
Thailand	310,366

1/ GDP for each country, provided in current national currencies by the International Monetary Fund, was converted to constant 1987 dollars.

SOURCE: International Monetary Fund, *International Financial Statistics Yearbook* (IMF: Washington, D.C., 1996).

have higher GDP growth rates than the United States or European countries (see NSF, 1993 and NSF, 1996c).

Japan is continuing to place its manufacturing industries and assembly offshore, mainly through investment in plants and equipment in developing Asian countries. Japan's direct foreign investment (FDI) in Asian countries reached $10 billion[26] in 1995, up from $5 billion in 1987 (Manifold, 1966). Through technology transfer and the education of significant numbers of foreign students from neighboring countries in engineering, health, and agriculture, Japan will continue to be one of the Asian region's growth engines. (See Chapter 4.) The Japanese Office of Development Assistance (ODA) is continuing its strong outreach program for more integration with China and South Korea, and for technical assistance to developing countries in the Asian region. There is need for research on the effectiveness of this three-pronged approach (direct foreign investment, technical assistance, and science and engineering education) to Japan's competitiveness in the Asian region, and Japan's role in fostering a prosperity sphere in East Asia.

[26] Market exchange rate conversion, not PPPs.

Methodology and Notes on Data Series

Purchasing Power Parities

Purchasing power parities (PPPs) are the preferred normalizer of international R&D data. Comparisons of international statistics on R&D are hampered by the fact that countries' R&D expenditures are denominated, obviously, in their home currencies. Two approaches are commonly used to normalize the data and facilitate aggregate R&D comparisons. The first method is to divide R&D by GDP, which results in indicators of relative effort vis-a-vis total economic activity. The second method is to convert all foreign-denominated expenditures to a single currency, which results in indicators of absolute effort. The first method is a straightforward calculation, but enables only gross national comparisons. The second permits finer inter-country comparisons, but first entails choosing an appropriate currency conversion series.

Since, for all practical purposes, there are not widely accepted R&D-specific exchange rates, the choice is between market exchange rates (MERS) and PPPs. These are the only series consistently compiled and available for a large number of countries over an extended period of time.

At their best, MERs represent the relative value of currencies for goods and services that are traded across borders—that is, MERs measure a currency's relative international buying power. But because sizable portions of most countries' economies do not engage in international activity, and because major fluctuations in MERs greatly reduce their statistical utility, an alternative currency conversion series—PPPs—has been developed. PPPs take into account the cost differences across countries of buying a similar basket of goods and services in numerous expenditure categories, including nontradables: The PPP basket is representative of total gross domestic product across countries. When applied to current R&D expenditures of major industrial countries such as Germany and Japan, PPPs result in a lower estimate of total research spending than do MERs. For example in 1994, Japan's R&D totaled $76 billion based on MERs and $54 billion based on PPPs. When applied to current R&D expenditures of developing countries such as China and India, PPPs result in a larger estimate of total research spending than do MERs.

PPPs are the preferred international standard for calculating cross-country R&D comparisons and are used, for example, in all official OECD R&D tabulations. Although there is considerable difference in what is included in GDP-based PPP items and R&D expenditure items, the major components of R&D costs-fixed assets and the wages of scientists, engineers, and support personnel-are more suitable to a domestic converter than to one based on foreign trade flows. Exchange rate movements bear little relationship to changes in the cost of domestically performed R&D.

Changes in dollar-denominated R&D expenditures converted with market exchange rates exhibit wild fluctuations, and are inappropriate for showing trends. PPP calculations result in R&D expenditure changes considerably closer to the countries' actual funding pattern.

Japan's present national currency was converted to constant 1987 national currency and then converted to 1987 constant PPPs ($PPP) using PPP conversion rates of the Organization for Economic Co-operation and Development (OECD).

OECD Adjusted Data for Japan

The national survey in Japan collects data for researchers as "persons working mainly in R&D" rather than in terms of full-time equivalent. Consequently, R&D personnel and labor cost data are overestimated by international standards. Recent studies by the Japanese authorities suggest that in order to reach FTE the numbers of researchers might, perhaps, be cut by 40 percent in the higher education sector and by about 30 percent in the business enterprise sector and for the national total. Therefore, higher education R&D (HERD) would be reduced by about 25 percent and business enterprise R&D (BERD) and gross expenditure R&D (GERD) cut by about 15 percent.

For some years OECD has calculated an "adjusted" Japanese series of data for the higher education sector, based on proportions observed in other member countries (less 50 percent of researchers and hence about 35 percent of HERD) and, thus, for the national totals (less 12.5 percent researchers and 10 percent GERD) for use in its own reports. (See OECD Science and Technology Indicators No. 2—R&D, Invention and Competitiveness, p. 75.) This OECD series does not make any adjustment to the business enterprise sector.

OECD "adjusted" series include a special analysis of the Japanese Science and Technology Budget by socio-economic objective prepared for OECD by Japanese consultants. The latter excludes most R&D in the social sciences and humanities.

Stock of Scientists and Engineers

The 1990 Japanese data presented in tables 1 and 2 are based on the U.S. Bureau of the Census, 1996 publication of *Scientists and Engineers in Japan: 1990*, which provides the results of a 13-percent sample tabulation of the 1990 Japanese Population Census. The prior years of Japanese data presented are taken from the previous SRS 1988 publication: *The Science and Technology Resources of Japan: A Comparison with the United States.* The U.S. 1980 data are from this previous SRS publication, while the 1986 and 1991 U.S. data presented are from the U.S. Bureau of the Census 1992 publication *Scientists and Engineers in Industrialized Societies*, which uses a 3-percent sample from each national census.

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Appendix:

Detailed Data Tables

Table A-1. National expenditures for the performance of R&D: 1975–96						
Year	Japan				United States	
	[Millions of current yen]	[Japan deflator]	[Millions of constant yen]	[PPP conversion]	[Millions of constant 1987 dollars 1/]	
1975......................	¥2,737,000	0.71	¥3,834,828	279.60	$18,172	$72,237
1976......................	3,054,400	0.77	3,992,396	283.60	18,919	75,043
1977......................	3,358,920	0.81	4,124,347	282.70	19,544	76,720
1978......................	3,725,080	0.85	4,392,906	276.70	20,817	80,070
1979......................	4,217,280	0.87	4,827,237	260.90	22,875	84,061
1980......................	4,826,320	0.91	5,319,981	250.00	25,210	87,649
1981......................	5,502,795	0.92	5,997,921	242.70	28,423	91,408
1982......................	6,014,874	0.93	6,453,178	232.50	30,580	95,541
1983......................	6,621,186	0.95	7,001,630	226.80	33,179	102,285
1984......................	7,302,421	0.97	7,546,886	223.20	35,763	111,201
1985......................	8,274,717	0.98	8,424,366	219.10	39,921	120,600
1986......................	8,562,752	1.00	8,562,752	217.50	40,577	123,321
1987......................	9,162,095	1.00	9,162,095	211.00	43,417	125,376
1988......................	9,931,859	1.00	9,900,822	203.90	46,917	127,831
1989......................	11,075,422	1.02	10,837,606	199.00	51,357	129,892
1990......................	12,277,538	1.04	11,749,604	195.30	55,678	133,999
1991......................	12,923,892	1.07	12,043,004	193.70	57,069	136,300
1992......................	13,001,112	1.09	11,917,686	186.70	56,475	136,197
1993......................	12,736,831	1.10	11,597,666	184.30	54,958	133,780
1994......................	12,626,894	1.10	11,464,836	181.10	54,329	133,483
1995 (prelim.)........	NA	1.10	NA	181.30	NA	139,408
1996 (prelim.)........	NA	1.09	NA	177.00	NA	140,893

1/ Conversion of Japanese yen to U.S. dollars is calculated with purchasing power parity exchange rates from the Organisation for Economic Co-operation and Development. Numbers for constant yen and constant dollars are derived from deflator and PPP data.

KEY: NA = not available

NOTES: R&D data for Japan are based on OECD's "adjusted series" for Japan, for better international comparability. (See Methodology and Notes on Data Series.) U.S. data are preliminary for 1995 and 1996. Constant 1987 dollars for the United States are based on U.S. Department of Commerce GDP implicit price deflators.

SOURCES: For Japan, 1981–94 data: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (MSTI), Paris, OECD, December,1996; for earlier data for Japan, 1975–80, OECD/MSTI 1990, special tabulations; for the United States, Science Resources Studies Division, National Science Foundation, *National Patterns of R&D Resources: 1996* , NSF 96-333 (Arlington, VA: NSF, 1996).

Table A-2. National expenditures for the performance of R&D as a percent of GDP: 1975–96

Year	GDP		R&D as a percent of GDP	
	Japan	United States	Japan	United States
	[Millions of constant 1987 dollars 1/]		[Percent]	
1975	$984,819	$3,224,029	1.9%	2.2%
1976	1,031,750	3,383,203	1.8	2.2
1977	1,080,058	3,533,381	1.8	2.2
1978	1,142,273	3,703,251	1.8	2.2
1979	1,201,690	3,796,537	1.9	2.2
1980	1,254,549	3,776,377	2.0	2.3
1981	1,332,408	3,843,013	2.1	2.4
1982	1,375,753	3,760,255	2.2	2.5
1983	1,411,938	3,906,666	2.4	2.6
1984	1,471,871	4,148,490	2.4	2.7
1985	1,545,840	4,279,676	2.6	2.8
1986	1,585,623	4,404,292	2.6	2.8
1987	1,651,093	4,539,930	2.6	2.8
1988	1,754,598	4,718,710	2.7	2.7
1989	1,837,158	4,839,447	2.8	2.7
1990	1,950,218	4,895,057	2.9	2.7
1991	2,026,702	4,868,027	2.8	2.8
1992	2,049,410	4,979,487	2.8	2.7
1993	2,051,471	5,136,275	2.7	2.6
1994	2,061,268	5,343,695	2.6	2.5
1995	2,079,285	5,520,671	NA	2.5
1996	2,126,761	5,670,229	NA	2.5

1/ Conversion of Japanese yen to U.S. dollars is calculated with purchasing power parity exchange rates from the Organisation for Economic Co-operation and Development.

KEY: NA = not available

NOTES: R&D data for Japan are based on OECD's "adjusted series" for Japan, for better international comparability. (See Methodology and Notes on Data Series.) Constant 1987 dollars for the United States are based on U.S. Department of Commerce calendar year GDP implicit price deflators.

SOURCES: For Japan, 1981–94 data: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (MSTI), Paris, OECD, December 1996; for earlier data for Japan, 1975–80, OECD/MSTI 1990, special tabulations; for the United States, Science Resources Studies Division, National Science Foundation, *National Patterns of R&D Resources: 1996* , NSF 96-333 (Arlington, VA: NSF, 1996).

Table A-3. Estimated nondefense R&D expenditures as a percent of GDP: 1975–96

Year	Total		Government	
	Japan	United States	Japan	United States
	[Millions of constant 1987 dollars1/]			
1981	$28,254	$68,021	$6,909	$19,242
1982	30,394	68,813	7,001	16,974
1983	32,981	72,273	7,069	16,869
1984	35,544	77,992	7,113	16,979
1985	39,638	83,454	7,342	18,100
1986	40,263	84,562	7,558	17,209
1987	43,065	85,805	8,158	18,343
1988	46,527	89,184	8,101	18,581
1989	49,603	93,885	8,196	19,181
1990	55,205	99,859	8,491	20,312
1991	56,561	105,636	8,851	20,658
1992	55,923	106,561	9,331	20,326
1993	54,366	104,780	10,235	19,956
1994	53,723	106,874	9,988	21,309
1995 (prelim.)	NA	112,622	10,138	22,073
1996 (prelim.)	NA	NA	11,530	NA
	[Percent]			
1981	2.1%	1.8%	0.52%	0.50%
1982	2.2	1.8	0.5	0.5
1983	2.3	1.9	0.5	0.4
1984	2.4	1.9	0.5	0.4
1985	2.6	2.0	0.5	0.4
1986	2.5	1.9	0.5	0.4
1987	2.6	1.9	0.5	0.4
1988	2.7	1.9	0.5	0.4
1989	2.7	1.9	0.5	0.4
1990	2.8	2.0	0.4	0.4
1991	2.8	2.2	0.4	0.4
1992	2.7	2.1	0.5	0.4
1993	2.7	2.0	0.5	0.4
1994	2.6	2.0	0.5	0.4
1995 (prelim.)	NA	2.0	0.5	0.4
1996 (prelim.)	NA	NA	0.5	NA

1/ Conversion of Japanese yen to U.S. dollars is calculated with purchasing power parity exchange rates from the Organisation for Economic Co-operation and Development.

KEY: NA = not available

NOTES: R&D data for Japan are based on OECD's "adjusted series" for Japan, for better international comparability. (See Methodology and Notes on Data Series.) Data are preliminary for 1995 and 1996. Constant 1987 dollars for the United States are based on U.S. Department of Commerce GDP implicit price deflators.

SOURCES: For Japan, 1981–94, Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (MSTI), Paris, OECD, December 1996; preliminary 1995–96 government data for Japan from Science and Technology Agency (STA) calculations, in National Science Foundation, Tokyo Office, Report Memorandum #96-5, February 2, 1996; for the United States, Science Resources Studies Division, National Science Foundation, *National Patterns of R&D Resources: 1996* , NSF 96-333 (Arlington, VA: NSF, 1996).

Table A-4. National R&D funding by source: 1975–97

Year	Japan			United States		
	Government	Industry	Univ. & private non-profit	Government	Industry	Univ. & private non-profit
	[Millions of constant 1987 dollars 1/]					
1975	$4,785	$11,391	$1,388	$37,396	$32,161	$2,679
1976	4,958	11,919	1,437	38,464	33,837	2,743
1977	5,156	12,445	1,324	38,793	35,117	2,810
1978	5,535	13,024	1,528	39,819	37,234	3,017
1979	6,242	14,634	1,518	41,157	39,762	3,142
1980	6,749	16,687	1,484	41,385	43,118	3,146
1981	7,077	19,242	2,103	42,629	45,563	3,217
1982	7,186	21,161	2,263	43,702	48,559	3,280
1983	7,266	23,457	2,455	46,881	51,896	3,509
1984	7,331	25,856	2,575	50,188	57,368	3,645
1985	7,625	29,541	2,755	55,246	61,418	3,937
1986	7,872	29,905	2,800	55,968	63,009	4,343
1987	8,510	31,911	2,996	57,914	62,643	4,819
1988	8,492	35,376	3,050	57,228	65,492	5,111
1989	8,628	39,596	3,184	55,188	69,169	5,534
1990	8,964	43,373	3,341	54,452	73,604	5,943
1991	9,359	44,171	3,538	51,322	78,652	6,326
1992	9,883	42,921	3,614	49,962	79,757	6,477
1993	10,827	40,339	3,902	48,956	78,306	6,518
1994	10,594	39,877	3,857	47,918	78,802	6,763
1995	10,806	NA	NA	48,859	83,702	6,847
1996	12,198	NA	NA	47,416	86,611	6,867
1997	13,053	NA	NA	NA	NA	NA

See explanatory information and SOURCE at end of table.

Table A-4. National R&D funding by source: 1975–97

Year	Japan			United States		
	Government	Industry	Univ. & private non-profit	Government	Industry	Univ. & private non-profit
	[Percent]					
	26.3%	62.7%	7.6%	51.4%	44.5%	3.7%
1977..................................	26.4	63.7	6.8	50.5	45.8	3.7
1978..................................	26.6	62.6	7.3	49.6	46.5	3.8
1979..................................	27.3	64.0	6.6	48.8	47.3	3.7
1980..................................	26.8	66.2	5.9	47.1	49.2	3.6
1981..................................	24.9	67.7	7.4	46.5	49.8	3.5
1982..................................	23.5	69.2	7.4	45.7	50.8	3.4
1983..................................	21.9	70.7	7.4	45.8	50.7	3.4
1984..................................	20.5	72.3	7.2	45.1	51.6	3.3
1985..................................	19.1	74.0	6.9	45.8	50.9	3.3
1986..................................	19.4	73.7	6.9	45.4	51.1	3.5
1987..................................	19.6	73.5	6.9	46.2	50.0	3.8
1988..................................	18.1	75.4	6.5	44.7	51.2	4.0
1989..................................	16.8	77.1	6.2	42.5	53.3	4.3
1990..................................	16.1	77.9	6.0	40.5	54.9	4.4
1991..................................	16.4	77.4	6.2	37.6	57.7	4.6
1992..................................	17.5	76.0	6.4	36.6	58.6	4.8
1993..................................	19.7	73.4	7.1	36.5	58.5	4.9
1994..................................	19.5	73.4	7.1	35.8	59.0	5.1
1995..................................	NA	NA	NA	35.0	60.0	4.9
1996..................................	NA	NA	NA	33.6	61.5	4.9

1/ Conversion of Japanese yen to U.S. dollars is calculated with purchasing power parity exchange rates from the Organisation for Economic Co-operation and Development.

KEY: NA = not available

NOTES: R&D data for Japan are based on OECD's "adjusted series" for Japan, for better international comparability. (See Methodology and Notes on Data Series.) U.S. data are preliminary for 1995 and 1996. Constant 1987 dollars for the United States are based on U.S. Department of Commerce GDP implicit price deflators. Japanese government data for 1995–96 are budget allocation data, not R&D expenditure data. The 1995 government R&D figure does not include the subsequent supplemental budget. Japan's 1997 government data are the Cabinet-approved budget, awaiting Diet approval.

SOURCES: For Japan, 1981–94 data: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (MSTI), Paris, OECD, December 1996; for earlier data for Japan, 1975–80, OECD/MSTI 1990, special tabulations; for the United States, Science Resources Studies Division, National Science Foundation, *National Patterns of R&D Resources: 1996* , NSF 96-333 (Arlington, VA: NSF, 1996).

Table A-5. National R&D expenditures, by performer: 1975–96

Year	Japan				United States			
	Government	Industry	Universities & colleges	Non-profit research inst	Government	Industry	Universities & colleges 2/	Non-profit research inst
	[Millions of constant 1987 dollars 1/]							
1975	$2,311	$11,186	$3,428	$945	$11,248	$49,161	$9,236	$2,593
1976	2,395	11,659	3,640	1,003	11,268	51,620	9,525	2,631
1977	2,463	12,274	3,664	879	10,852	53,354	9,839	2,674
1978	2,704	12,803	3,982	1,020	11,426	55,231	10,641	2,773
1979	2,956	14,455	4,218	915	11,465	58,271	11,285	3,040
1980	3,108	16,413	4,304	1,008	10,810	62,071	11,769	2,999
1981	3,411	18,748	4,573	1,279	10,830	65,665	11,997	2,915
1982	3,425	20,535	4,821	1,407	10,934	69,988	11,725	2,894
1983	3,451	22,851	5,153	1,394	12,163	74,849	12,206	3,068
1984	3,541	25,156	5,210	1,502	12,730	82,198	12,948	3,324
1985	3,912	28,657	5,188	1,677	13,727	89,236	14,009	3,628
1986	3,977	29,002	5,316	1,907	13,939	90,633	15,255	3,483
1987	4,472	30,775	5,732	2,084	13,413	92,155	16,358	3,450
1988	4,410	34,104	5,856	2,158	13,625	93,373	17,368	3,465
1989	4,417	38,180	6,082	2,311	13,886	94,060	18,213	3,733
1990	4,454	42,026	6,378	2,450	14,151	96,846	18,637	4,148
1991	4,623	43,023	6,451	2,511	12,972	99,449	19,266	4,464
1992	5,026	41,530	6,803	2,654	12,975	98,519	19,897	4,673
1993	5,496	39,065	7,273	2,693	13,547	95,061	20,433	4,656
1994 3/	5,270	38,639	7,252	2,771	12,870	94,841	20,898	4,758
1995	NA	NA	NA	NA	12,843	100,390	21,295	4,797
1996	NA	NA	NA	NA	12,442	102,443	21,221	4,656

See explanatory information and SOURCE at end of table.

Table A-5. National R&D expenditures, by performer: 1975–96

Year	Japan				United States			
	Government	Industry	Universities & colleges	Non-profit research inst	Government	Industry	Universities & colleges 2/	Non-profit research inst
	[Percent]							
1977	12.6%	62.8%	18.7%	4.5%	14.1%	69.5%	12.8%	3.5%
1978	13.0	61.5	19.1	4.9	14.3	69.0	13.3	3.5
1979	12.9	63.2	18.4	4.0	13.6	69.3	13.4	3.6
1980	12.3	65.1	17.1	4.0	12.3	70.8	13.4	3.4
1981	12.0	66.0	17.6	4.5	11.8	71.8	13.1	3.2
1982	11.2	67.2	17.1	4.6	11.4	73.3	12.3	3.0
1983	10.4	68.9	16.5	4.2	11.9	73.2	11.9	3.0
1984	9.9	70.3	15.5	4.2	11.4	73.9	11.6	3.0
1985	9.8	71.8	14.2	4.2	11.4	74.0	11.6	3.0
1986	9.8	71.5	14.0	4.7	11.3	73.5	12.4	2.8
1987	10.3	70.9	14.0	4.8	10.7	73.5	13.0	2.8
1988	9.4	72.7	13.3	4.6	10.7	73.0	13.6	2.7
1989	8.6	74.3	12.5	4.5	10.7	72.4	14.0	2.9
1990	8.0	75.5	12.2	4.4	10.6	72.3	13.9	3.1
1991	8.1	75.4	12.1	4.4	9.5	73.0	14.1	3.3
1992	8.9	73.5	12.8	4.7	9.5	72.3	14.6	3.4
1993	10.0	71.1	14.0	4.9	10.1	71.1	15.3	3.5
1994	9.7	71.1	14.3	5.1	9.6	71.1	15.7	3.6
1995	NA	NA	NA	NA	9.2	72.0	15.3	3.4
1996	NA	NA	NA	NA	8.8	72.7	15.1	3.3

1/ Conversion of Japanese yen to U.S. dollars is calculated with purchasing power parity exchange rates from the Organisation for Economic Co-operation and Development.

2/ In the U.S. data, universities and colleges include federally funded research and development centers (FFRDCs).

3/ In the Japanese data, performance by universities and non-profit institutes is estimated for 1994.

KEY: NA = not available

NOTES: R&D data for Japan are based on OECD's "adjusted series" for Japan, for better international comparability (See Methodology and Notes on Data Series). U.S. data are preliminary for 1995 and 1996. Constant 1987 dollars for the United States are based on U.S. Department of Commerce GDP implicit price deflators. Japanese government data for 1995–97 are budget allocation data, not R&D expenditure data.

SOURCES: For Japan, 1981–94 data: Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (MSTI). Paris, OECD, Dec.,1996; for earlier data for Japan, 1975–80, OECD/MSTI 1990, special tabulations; for the United States, Science Resources Studies Division, National Science Foundation, *National Patterns of R&D Resources: 1996* , NSF 96-333 (Arlington, VA: NSF, 1996).

Table A-6. R&D Expenditures in Selected Countries by Characteristic of Work: 1980–93								
	United States				Japan			
Year	Basic Research	Applied Research	Development	Total	Basic Research	Applied Research	Development	Total
	[Millions of constant 1987 dollars 1/]							
1980	$11,902	$19,078	$56,669	$87,649	$3,882	$6,403	$15,125	$25,411
1981	12,303	20,825	58,280	91,408	4,149	7,304	16,996	28,450
1982	12,480	21,674	61,387	95,541	4,495	7,920	18,195	30,610
1983	13,377	23,252	65,657	102,286	4,844	8,427	19,940	33,212
1984	14,223	24,607	72,371	111,201	5,042	8,976	21,743	35,762
1985	15,066	26,836	78,698	120,600	5,349	9,980	24,631	39,960
1986	17,121	27,933	78,266	123,320	5,599	9,900	25,116	40,615
1987	18,025	27,687	79,664	125,376	6,295	10,550	26,571	43,416
1988	18,351	28,145	81,334	127,830	6,474	11,354	29,088	46,916
1989	19,549	29,726	80,616	129,891	6,830	12,274	32,251	51,355
1990	19,789	30,756	83,445	133,990	7,238	13,474	34,965	55,677
1991	22,513	32,886	80,902	136,301	7,642	14,135	35,682	57,459
1992	22,212	31,324	82,661	136,197	7,799	13,886	35,113	56,798
1993	22,719	30,162	80,901	133,782	NA	NA	NA	NA
1994	22,923	29,067	81,495	133,485	NA	NA	NA	NA
1995	22,987	29,309	87,112	139,408	NA	NA	NA	NA
1996	22,814	29,634	88,445	140,893	NA	NA	NA	NA
	[Percent]							
1980	13.6%	21.8%	64.7%	100%	15.4%	25.3%	59.3%	100%
1981	13.5	22.8	63.8	100	14.6	25.6	59.8	100
1982	13.1	22.7	64.3	100	14.7	25.8	59.5	100
1983	13.1	22.7	64.2	100	14.6	25.3	60.1	100
1984	12.8	22.1	65.1	100	14.1	25.1	60.8	100
1985	12.5	22.3	65.3	100	13.4	24.9	61.7	100
1986	13.9	22.7	63.5	100	13.8	24.4	61.9	100
1987	14.4	22.1	63.5	100	14.5	24.3	61.2	100
1988	14.4	22.0	63.6	100	13.8	24.2	62.0	100
1989	15.1	22.9	62.1	100	13.3	23.9	62.8	100
1990	14.8	23.0	62.3	100	13.0	24.2	62.8	100
1991	16.5	24.1	59.4	100	13.3	24.6	62.1	100
1992	16.3	23.0	60.7	100	13.9	24.4	61.7	100
1993	17.0	22.5	60.5	100	NA	NA	NA	NA
1994	17.2	21.8	61.1	100	NA	NA	NA	NA
1995	16.5	21.0	62.5	100	NA	NA	NA	NA
1996	16.2	21.0	62.8	100	NA	NA	NA	NA

1/ Conversion of Japanese yen to U.S. dollars is calculated with purchasing power parity exchange rates from the Organisation for Economic Co-operation and Development.

KEY: NA = not applicable

NOTES: U.S. data are preliminary for 1995 and 1996. Constant 1987 dollars for the United States are based on U.S. Department of Commerce GDP implicit price deflators.

SOURCES: For Japan, Government of Japan, National Institute of Science and Technology Policy, Science and Technology Agency, *Science and Technology Indicators: 1994* , NISTEP Report No. 37 (Tokyo, 1995); for the United States, Science Resources Studies Division, National Science Foundation, *National Patterns of R&D Resources: 1996* , NSF 96-333 (Arlington, VA: NSF, 1996).

Table A-7. Scientists and engineers engaged in R&D: 1975–94				
Year	Japan	United States	Japan	United States
			Per 10,000 labor force	
1975	253,488	527,400	45.5	55.3
1976	263,486	535,200	47.1	54.7
1977	265,174	560,600	47.1	55.7
1978	273,190	586,600	48.3	56.5
1979	290,827	614,500	51.2	57.7
1980	303,524	651,100	53.2	60.0
1981	310,993	683,300	54.0	61.9
1982	320,991	711,900	56.0	63.6
1983	347,420	751,700	59.0	66.4
1984	357,416	797,800	60.0	69.2
1985	380,761	801,900	64.0	68.4
1986	392,981	838,992	65.0	70.2
1987	415,553	877,800	68.0	72.2
1988	434,643	900,701	70.0	73.0
1989	457,522	924,200	73.0	73.6
1990	477,866	942,126	75.0	74.5
1991	491,102	960,400	75.0	75.7
1992	511,407	961,549	78.0	75.0
1993	526,501	962,700	80.0	74.3
1994	541,015	NA	NA	NA

KEY: NA = not available

NOTES: Japanese data are based on OECD's "adjusted series" for Japan and include persons primarily employed in R&D in the natural sciences and engineering. (See Methodology and Notes on Data Series.) The U.S. data are a mix of S&Es engaged in R&D on an FTE basis and counts of S&Es whose primary work activity is R&D. U.S. data are imputed for 1986, 1988, 1990, and 1992.

SOURCES: For Japan, 1981–94 data: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators (MSTI),* Paris, OECD, December 1996; for earlier data for Japan, 1975–80, OECD/MSTI 1990, special tabulations; for the United States, Science Resources Studies Division, National Science Foundation, *National Patterns of R&D Resources: 1996* , NSF 96-333 (Arlington, VA: NSF, 1996).

Table A-8. Distribution of government R&D funding by objective: selected years						
Objective	Japan			United States		
	1985	1989	1994	1985	1989	1994
	[Percent]					
Agriculture, forestry, and fisheries	11.3%	3.7%	3.5%	2.1%	1.9%	1.8%
Industrial development	5.9	4.6	3.7	0.2	0.2	0.1
Energy	16.3	22.2	20.5	4.8	3.9	4.2
Health	2.6	2.7	3.0	11.2	12.9	16.1
Advancement of knowledge	47.3	51.1	51.2	3.7	3.8	4.0
Advancement of research	NA	7.8	9.1	3.7	3.8	4.0
GUF	NA	43.3	42.1	NA	NA	NA
Civil space	6.8	6.4	7.5	5.5	7.3	10.9
Defense	4.1	5.1	6.5	67.5	65.5	55.3
All others	5.7	4.2	4.6	5.0	4.5	3.6

KEY: NA = not available

SOURCES: Government of Japan, National Institute of Science and Technology Policy, Science and Technology Agency, *Science and Technology Indicators: 1994* , NISTEP Report No. 37 (Tokyo, 1995); Science Resources Studies Division, National Science Foundation, *National Patterns of R&D Resources: 1996,* NSF 96-333 (Arlington, VA: NSF, 1996).

Table A-9. Distribution of Japanese Government R&D budget among key Japanese ministeries and agencies: selected years

Ministry/agency	1990	1994	1997 1/	1990	1994	1997
	[Million of constant 1987 dollars]			[Percent]		
Total 2/	$8,711	$9,977	$12,779	100%	100%	100%
Ministry of Education, Science, and Culture	4,056	4,896	5,508	47	49	43
Science and Technology Agency	2,244	2,560	3,102	26	26	24
Ministry of International Trade and Industry	1,141	1,200	1,974	13	12	15
Ministry of Agriculture, Forestry, and Fisheries	318	350	416	4	4	3
Defense Agency	473	596	744	5	6	6
Ministry of Health and Welfare	232	296	379	3	3	3
All others	247	79	639	3	1	5

1/ 1997 approved government budget for science and technology.

2/ Does not include local government funding of R&D.

SOURCES: Government of Japan, National Institute of Science and Technology Policy, Science and Technology Agency (STA), *Science and Technology Indicators: 1994,* MISTEP Report No. 37 (Tokyo, 1996) and STA, "Science and Technology Budget of the Government for FY1997" (Draft).

Table A-10. R&D performance by industry

Industry	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
	United States												
	[Millions of constant 1987 dollars]												
Total business enterprise	$65,699	$70,021	$74,883	$82,153	$89,265	$90,614	$92,155	$93,418	$94,060	$96,846	$99,449	$98,519	95,000
Total manufacturing	63,282	67,070	71,054	76,766	82,150	82,931	84,311	83,295	81,128	78,494	75,260	74,588	70,538
Food, beverages, and tobacco	809	930	949	1,188	1,204	1,327	1,206	1,176	1,172	1,253	1,086	1,146	1,122
Textiles, apparel, and leather	147	162	172	199	231	254	243	249	239	263	253	241	236
Wood products and furniture	204	190	174	157	156	149	137	165	181	217	188	216	211
Paper, paper products, and printing	718	676	634	651	610	558	604	754	828	1,063	1,106	1,089	1,066
Chemicals, except drugs and medicines	4,489	4,909	4,901	5,061	5,358	5,350	5,535	5,616	5,771	6,182	6,452	6,151	6,022
Drugs and medicines	2,644	2,975	3,343	3,646	3,692	3,774	4,100	5,041	5,353	5,549	6,004	6,571	6,432
Petroleum refineries and products	2,455	2,556	2,591	2,539	2,352	2,082	1,897	1,923	2,009	2,035	2,124	1,883	1,844
Rubber and plastic products	982	921	890	865	716	744	607	720	813	1,021	1,107	1,158	1,134
Non-metallic mineral products	583	612	716	805	884	980	995	706	585	545	433	446	436
Basic metal industries	1,113	1,178	1,245	787	784	829	730	613	632	652	607	432	423
Metal products	791	746	804	925	878	923	783	848	833	829	828	841	823
Non-electrical machinery	3,065	2,878	2,744	2,641	2,537	2,472	2,428	2,744	2,616	2,430	3,023	2,923	2,862
Office and computing machinery	5,581	6,766	7,613	8,896	10,408	10,105	9,347	9,935	10,717	10,320	9,541	9,433	9,234
Electrical machinery, except communication equipment	4,408	3,412	3,230	2,030	1,353	1,290	1,239	1,064	960	925	892	864	846
Radio, TV, and communication equipment	8,690	9,629	11,319	13,103	13,940	14,166	14,609	12,541	11,315	10,902	10,515	10,187	9,972
Shipbuilding and repairing	0	0	0	0	0	0	0	0	0	0	0	0	0
Motor vehicles	6,094	5,727	6,101	6,652	7,401	10,042	9,279	9,711	10,157	9,052	8,833	8,208	8,036
Aircraft	15,176	17,253	17,676	20,712	23,557	21,719	24,458	23,272	20,582	18,213	14,140	14,192	13,893
Other transport equipment	186	238	437	438	393	508	509	502	468	415	350	341	334
Professional goods	4,583	4,692	4,894	5,054	5,312	5,265	5,222	5,325	5,523	6,227	7,402	7,892	7,726
Other manufacturing, nec	563	619	621	416	382	394	383	390	373	402	375	374	366
Total services	2,417	2,951	3,829	5,387	7,115	7,683	7,844	10,123	12,932	18,352	24,189	23,931	24,462
Electricity, gas, and water	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	242	236
Construction	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Transport and storage	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Communications	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4,391	4,299
Commercial and engineering services	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other services	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

See explanatory information and SOURCE at end of table.

Table A-10. R&D performance by industry

Industry	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
	Japan												
	[Millions of constant 1987 dollars]												
Total business enterprise	18,748	20,535	22,851	25,156	28,657	29,002	30,775	34,104	38,180	42,026	43,318	41,851	39,252
Total manufacturing	17,916	19,695	21,882	24,088	27,606	27,942	29,698	32,847	36,789	40,364	41,694	40,063	37,470
Food, beverages, and tobacco	515	580	600	652	703	759	916	923	1,017	1,068	1,003	1,015	1,089
Textiles, apparel, and leather	333	264	256	291	302	297	315	344	377	400	408	519	403
Wood products and furniture	64	66	103	65	59	74	76	84	139	112	138	120	134
Paper, paper products, and printing	107	141	186	210	245	239	261	322	367	391	407	327	315
Chemicals, except drugs and medicines	2,060	2,276	2,429	2,730	2,868	3,040	3,389	3,656	3,978	4,085	4,258	4,208	4,042
Drugs and medicines	1,128	1,219	1,453	1,446	1,649	1,621	1,804	1,966	2,114	2,340	2,624	2,816	2,728
Petroleum refineries and products	210	222	250	274	329	325	333	354	390	417	394	394	355
Rubber and plastic products	499	530	549	649	701	712	811	909	1,078	1,041	1,138	1,092	1,033
Non-metallic mineral products	434	476	568	643	841	889	843	938	1,027	976	1,155	938	860
Basic metal industries	1,226	1,296	1,303	1,370	1,645	1,732	1,657	1,748	1,832	2,015	2,263	2,004	1,884
Metal products	334	330	415	409	495	449	449	423	507	588	610	555	522
Non-electrical machinery	1,707	1,851	1,984	2,158	2,415	2,398	2,522	2,671	3,125	3,635	3,732	3,486	3,475
Office and computing machinery	717	829	1,008	1,488	1,670	1,763	2,212	2,847	3,769	4,060	4,144	3,607	3,477
Electrical machinery, except communication equipment	1,766	1,961	2,293	2,636	2,973	2,936	3,155	3,504	4,018	4,518	4,491	4,235	4,208
Radio, TV, and communication equipment	3,097	3,707	4,209	4,493	5,433	5,260	5,554	6,065	6,138	6,584	6,956	6,984	6,145
Shipbuilding and repairing	42	47	58	44	53	39	42	45	54	59	65	84	79
Motor vehicles	2,583	2,754	2,884	3,262	3,670	3,787	3,753	4,348	4,970	5,798	5,620	5,546	4,633
Aircraft	127	139	221	112	184	256	280	231	287	361	472	289	305
Other transport equipment	138	138	131	120	173	175	99	72	78	78	77	75	76
Professional goods	655	682	796	820	973	944	968	1,128	1,234	1,523	1,396	1,432	1,394
Other manufacturing, nec	174	187	187	218	222	249	259	268	288	315	344	339	314
Total services	740	739	862	955	926	939	956	1,087	1,256	1,477	1,419	1,629	1,625
Electricity, gas, and water	272	247	284	316	306	329	308	347	349	441	403	481	477
Construction	376	410	508	569	535	574	608	701	859	964	910	1,066	1,076
Transport and storage	92	91	78	76	90	33	40	36	45	71	106	81	73
Communications	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Commercial and engineering services	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other services	7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

KEY: NA = not available

NOTE: Categories are taken from international Standard Industrial Classification, revision 2.

SOURCES: Organization for Economic Co-operation and Development (OECD), Structural Analysis Database for Industrial Analysis, Analytical Business Enterprise R&D (STAN/ANBERD) file (Paris: OECD,1995); OECD, Main Science and Technology Indicators database (Paris, 1995).

Table A-11. Industrial R&D expenditures as a percent of GDP: 1975–95			
Year	Japanese industrial R&D	U.S. total industrial R&D	U.S. company-supported R&D
	[Percent]		
1975	1.2%	1.5%	1.0%
1976	1.2	1.5	1.0
1977	1.2	1.5	1.0
1978	1.1	1.5	1.0
1979	1.2	1.5	1.0
1980	1.3	1.6	1.1
1981	1.4	1.7	1.2
1982	1.5	1.9	1.3
1983	1.7	1.9	1.3
1984	1.8	2.0	1.4
1985	1.9	2.1	1.4
1986	1.9	2.1	1.4
1987	1.9	2.0	1.4
1988	2.0	2.0	1.4
1989	2.2	1.9	1.4
1990	2.2	2.0	1.5
1991	2.2	2.0	1.6
1992	2.1	2.0	1.6
1993	2.0	1.9	1.5
1994	1.9	1.8	1.5
1995	NA	1.8	1.5

NA = not available

SOURCES: For Japan, 1981–94 data: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators (MSTI),* Paris, OECD, December 1996; for earlier data for Japan, 1975–80, OECD/MSTI 1990, special tabulations; for the United States, Science Resources Studies Division, National Science Foundation, *National Patterns of R&D Resources: 1996* , NSF 96-333 (Arlington, VA: NSF, 1996).

Table A-12. Proportion of R&D expenditures, by industry: 1993

Industry	Japan	U.S.
	[Percent]	
Food, beverages, and tobacco	2.8%	1.2%
Textiles, apparel, and leather	1.0	0.2
Wood products and furniture	0.3	0.2
Paper, paper products, and printing	0.8	1.1
Chemicals, except drugs and medicines	10.3	6.2
Drugs and medicines	6.9	6.7
Petroleum refineries and products	0.9	1.9
Rubber and plastic products	2.6	1.2
Non-metallic mineral products	2.2	0.5
Basic metal industries	4.8	0.4
Metal products	1.3	0.9
Non-electrical machinery	8.9	3.0
Office and computing machinery	8.9	9.6
Electrical machinery, except communication equipment	10.7	0.9
Radio, TV, and communication equipment	15.7	10.3
Shipbuilding and repairing	0.2	0.0
Motor vehicles	11.8	8.3
Aircraft	0.8	14.4
Other transport equipment	0.2	0.3
Professional goods	3.6	8.0
Other manufacturing, nec	0.8	0.4
Total services	4.1	24.3
Electricity, gas, and water	1.2	0.2
Construction	2.7	0.0
Transport and storage	0.2	0.0
Communications	0.0	4.5
Commercial and engineering services	0.0	0.0
Other services	0.0	0.0

SOURCES: Organization for Economic Co-operation and Development (OECD), Structural Analysis Database for Industrial Analysis, Analytical Business Enterprise R&D (STAN/ANBERD) file (Paris, OECD, 1995).

Table A-13. R&D expenditures as a percent of net sales: 1981–93

Industry	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
	United States												
	[Percent]												
Total manufacturing	2.5%	2.9%	3.0%	3.1%	3.4%	3.5%	3.4%	3.2%	3.1%	3.1%	3.1%	3.1%	2.8%
Food, beverages, and tobacco	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3
Textiles, apparel, and leather	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Wood products and furniture	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2
Paper, paper products, and printing	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5
Chemicals, except drugs and medicines	1.6	1.9	1.8	1.8	1.9	1.9	1.8	1.7	1.8	1.9	2.0	1.9	2.3
Drugs and medicines	9.5	10.2	10.6	11.4	11.0	10.4	10.6	12.0	11.9	11.8	11.5	11.9	13.2
Petroleum refineries and products	0.9	1.0	1.2	1.2	1.2	1.6	1.5	1.5	1.5	1.3	1.6	1.5	1.5
Rubber and plastic products	1.5	1.4	1.3	1.1	0.9	1.0	0.7	0.8	0.9	1.1	1.3	1.2	1.0
Non-metallic mineral products	1.0	1.2	1.3	1.3	1.5	1.6	1.7	1.2	1.0	1.0	0.8	0.9	1.0
Basic metal industries	0.6	1.0	1.0	0.6	0.7	0.8	0.6	0.4	0.4	0.5	0.5	0.4	0.5
Metal products	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Non-electrical machinery	1.5	1.7	1.8	1.6	1.6	1.6	1.5	1.6	1.5	1.4	1.9	1.9	1.6
Office and computing machinery	12.4	13.7	14.3	14.2	17.1	18.6	17.3	17.1	19.4	20.2	21.0	19.8	8.1
Electrical machinery, except communication equipment	7.8	7.1	6.5	3.5	2.3	2.2	1.7	1.3	1.2	1.3	1.3	1.3	1.0
Radio, TV, and communication equipment	11.5	12.6	13.8	13.1	13.7	13.7	15.8	12.7	11.6	11.3	10.8	9.8	8.6
Shipbuilding and repairing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Motor vehicles	4.1	4.3	3.5	3.3	3.6	4.9	4.5	4.5	4.8	4.7	5.0	4.2	4.0
Aircraft	18.0	20.3	20.2	21.7	23.3	20.2	22.4	21.3	18.0	16.1	12.5	13.6	13.3
Professional goods	4.4	4.6	4.8	4.4	4.9	4.7	4.9	4.9	5.1	5.7	6.9	7.4	7.8
Other manufacturing, nec	1.6	1.8	1.9	1.3	1.3	1.3	1.2	1.1	1.0	1.1	1.1	1.1	1.1

See explanatory information and SOURCE at end of table.

Table A-13. R&D expenditures as a percent of net sales: 1981–93

Industry	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
	Japan												
	[Percent]												
Total manufacturing	1.3%	1.5%	1.6%	1.7%	1.9%	2.1%	2.2%	2.3%	2.4%	2.5%	2.5%	2.5%	2.5%
Food, beverages, and tobacco	0.4	0.4	0.4	0.4	0.4	0.5	0.6	0.6	0.6	0.7	0.6	0.6	0.7
Textiles, apparel, and leather	0.5	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.8	0.7
Wood products and furniture	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.4	0.3	0.4	0.3	0.4
Paper, paper products, and printing	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.3
Chemicals, except drugs and medicines	1.5	1.6	1.7	1.9	2.0	2.3	2.5	2.6	2.7	2.6	2.7	2.8	2.8
Drugs and medicines	5.7	5.8	6.7	6.9	7.8	7.3	7.5	7.7	7.9	8.6	9.8	10.3	9.9
Petroleum refineries and products	0.2	0.2	0.3	0.4	0.5	0.7	0.9	1.0	1.0	0.9	0.9	0.9	0.9
Rubber and plastic products	1.0	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.4	1.5	1.5	1.5
Non-metallic mineral products	1.0	1.1	1.4	1.5	2.0	2.2	2.1	2.2	2.3	2.1	2.4	2.1	2.0
Basic metal industries	0.7	0.7	0.8	0.8	1.0	1.2	1.2	1.1	1.1	1.2	1.3	1.4	1.4
Metal products	0.7	0.7	0.9	0.8	0.9	0.8	0.8	0.7	0.8	0.8	0.8	0.7	0.7
Non-electrical machinery	1.5	1.7	2.0	2.0	2.2	2.3	2.7	2.4	2.5	2.6	2.6	2.7	3.0
Office and computing machinery	3.4	3.6	3.5	4.2	4.3	4.6	5.5	6.5	7.7	7.6	7.3	6.8	7.1
Electrical machinery, except communication equipment	3.1	3.4	3.7	3.8	4.0	3.9	4.0	4.1	4.3	4.6	4.2	4.2	4.6
Radio, TV, and communication equipment	4.1	4.8	4.7	3.9	4.8	4.7	5.0	4.9	4.6	4.8	4.8	5.5	5.1
Shipbuilding and repairing	0.3	0.3	0.4	0.3	0.4	0.4	0.6	0.6	0.7	0.6	0.6	0.7	0.7
Motor vehicles	2.1	2.3	2.3	2.5	2.6	2.7	2.6	2.8	2.9	3.2	3.0	3.0	2.7
Aircraft	7.4	6.6	9.5	4.4	6.1	8.9	8.4	6.7	8.2	10.4	13.7	7.7	8.1
Other transport equipment	3.1	3.6	3.5	3.3	4.9	5.2	3.0	2.1	2.0	1.8	1.8	1.5	1.8
Professional goods	3.4	3.8	4.5	4.4	4.7	4.8	5.2	5.6	5.8	6.8	5.9	6.8	7.6
Other manufacturing, nec	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.4

SOURCE: Organization for Economic Co-operation and Development (OECD), Structural Analysis Database for Industrial Analysis, Analytical Business Enterprise R&D (STANBERD) file and Net sales file (Paris: OECD, 1996).

Table A-14. Number of industrial scientists and engineers engaged in R&D: 1975–95

Year	Japan	United States
1975	146,604	361,700
1976	145,216	363,900
1977	151,437	373,600
1978	153,706	393,600
1979	157,279	414,200
1980	173,244	437,300
1981	184,889	498,800
1982	192,942	525,400
1983	201,137	562,500
1984	223,882	603,300
1985	231,097	646,800
1986	251,771	683,400
1987	260,846	702,200
1988	279,298	715,600
1989	294,202	733,100
1990	313,948	758,500
1991	330,996	776,400
1992	340,809	783,800
1993	356,406	764,500
1994	367,278	758,800
1995	376,639	NA

KEY: NA = not available

NOTE: Japanese data include mainly regular researchers employed in R&D in industry and a tiny fraction (0.4 percent) of external non-regular workers. Assistant research workers and technicians are not included. U.S. data are full time equivalent (FTE) R&D scientists and engineers in R&D performing companies.

SOURCES: For Japanese data 1975–94, Government of Japan, National Institute of Science and Technology Policy, Science and Technology Agency, *Science and Technology Indicators: 1994,* NISTEP Report No. 37 (Tokyo, 1995); for 1995 data, Statistics Bureau, Management and Coordination Agency, *Report on the Survey of Research and Development, 1995* ; for the U.S. data for 1984–94, Science Resources Studies Division, National Science Foundation, *National Patterns of R&D Resources: 1996,* (Arlington, VA); for prior years, NSF/SRS *Research and Development in Industry,* annual series.

Table A-15. R&D scientists and engineers per 10,000 employees in manufacturing companies, by industry

Industry	Japan			United States		
	1985	1990	1993	1985	1990	1993
All manufacturing, total	468	577	622	430	470	520
Food	225	230	235	80	80	90
Textiles	213	280	337	50	60	70
Chemicals and allied products	784	938	960	570	690	800
Industrial chemicals	711	853	884	390	590	580
Drugs and medicines	796	875	934	810	960	1,380
Petroleum and coal	394	455	427	210	260	270
Rubber	363	481	492	260	320	240
Ceramics	355	372	450	200	240	210
Iron and steel	177	247	262	110	70	90
Non-ferrous metals	316	349	371	160	150	150
Fabricated metals	260	255	268	NA	200	210
General machinery	425	472	508	600	730	610
Electrical machinery	767	978	1,018	NA		
Electrical equipment	647	770	794	530	660	750
Communications and electronic equipment	836	1,094	1,140	620	890	NA
Motor vehicles	331	458	517	280	430	540
Professional and scientific instruments	664	831	877	NA	710	NA
Aircraft and missiles	NA	NA	NA	1,160	960	940

KEY: NA = not available

NOTES: Table uses industry field names as given in National Science Foundation, *Science & Engineering Indicators, 1996.* Japanese data include mainly regular researchers employed in R&D in industry and a tiny fraction (0.4 percent) of external non-regular workers. Assistant research workers and technicians are not included. U.S. data are full time equivalent (FTE) R&D scientists and engineers in R&D performing companies.

SOURCES: Government of Japan, National Institute of Science and Technology Policy, Science and Technology Agency, *Science and Technology Indicators: 1994* , NISTEP Report No. 37 (Tokyo, 1995); and the National Science Foundation, Science Resources Studies Division, *Research and Development in Industry: 1993,* NSF 96-304 (NSF: Arlington, VA,1996)

Table A-16. First university degrees in science and engineering, by field: 1975–94

Field	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
					Japan					
Total	313,072	326,167	339,819	356,981	374,887	378,666	386,057	382,466	369,069	372,247
Natural science 1/	7,014	7,483	7,479	7,985	8,248	8,636	8,651	8,710	8,575	9,054
Mathematics	2,490	2,529	2,755	2,703	2,829	2,918	3,152	3,045	3,148	3,180
Agricultural science	9,480	9,965	10,455	10,937	12,794	11,182	11,555	11,016	10,658	11,189
Social science	134,645	139,258	143,416	151,519	158,023	158,394	160,520	159,450	151,996	151,626
Engineering/computer sci.	66,512	68,126	70,431	72,466	75,409	74,737	76,370	74,774	70,824	71,640
Other	92,931	98,806	105,283	111,371	117,584	122,799	125,809	125,471	123,868	125,558
					United States					
Total	931,663	934,443	928,228	930,197	931,340	940,251	946,877	964,043	980,679	986,345
Natural science 1/	70,578	73,258	72,980	71,334	68,489	66,446	63,896	62,619	60,145	59,172
Mathematics	18,346	16,085	14,303	12,701	11,901	11,473	11,183	11,708	12,557	13,342
Computer science	5,039	5,664	6,426	7,224	8,769	11,213	15,223	20,431	24,682	32,435
Agricultural science	16,531	18,289	20,199	21,027	21,631	21,121	20,166	19,235	19,170	17,303
Social science	163,147	157,405	148,533	144,018	138,903	135,632	132,607	133,565	128,651	126,078
Engineering	39,824	38,790	41,357	47,251	53,469	58,810	63,717	67,460	72,670	76,153
Other	618,198	624,952	624,430	626,642	628,178	635,556	640,085	649,025	662,804	661,862

Field	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
					Japan					
Total	373,302	376,260	382,655	382,828	376,688	400,103	428,079	437,878	445,774	461,898
Natural science 1/	9,166	9,435	9,817	9,895	9,900	9,866	10,452	10,386	10,757	11,470
Mathematics	3,532	3,379	3,572	3,493	3,395	3,554	3,765	3,790	4,221	4,574
Agricultural science	10,928	10,991	11,266	10,584	10,252	11,733	12,282	12,284	13,021	13,361
Social science	151,072	151,056	150,956	150,819	147,087	157,477	170,721	177,240	179,338	186,580
Engineering/computer sci.	72,560	74,516	77,077	77,503	77,009	81,355	87,397	88,385	88,406	91,184
Other	126,044	126,883	129,967	130,534	129,045	136,118	143,462	145,793	150,031	154,739
					United States					
Total	990,880	1,000,352	1,000,532	1,006,033	1,030,171	1,062,151	1,107,997	1,150,072	1,179,276	1,183,141
Natural science 1/	59,550	57,759	52,642	50,403	49,301	54,241	56,757	62,837	68,880	70,844
Mathematics	15,267	16,388	16,626	16,122	15,439	14,674	14,784	14,931	14,853	14,631
Computer science	39,121	42,195	39,927	34,896	30,963	27,695	25,410	24,958	24,580	24,553
Agricultural science	15,879	14,740	16,082	14,331	13,559	8,411	8,432	8,432	8,432	12,947
Social science	125,033	127,558	131,935	136,717	146,737	159,368	170,105	182,166	186,585	187,273
Engineering	77,572	76,820	74,425	70,154	66,947	64,705	62,187	61,941	62,705	63,012
Other	658,458	664,892	668,895	683,410	707,225	733,057	770,322	794,807	813,241	809,880

1/ Natural sciences include physical, biological, earth, atmospheric, and oceanographic sciences.

2/ In Japanese data, engineering includes computer science.

SOURCES: Government of Japan, Ministry of Education, Science and Culture, Basic Education Survey, 1993; and the National Science Foundation, SRS, *Science and Engineering Degrees 1966–94,* NSF 96-321 (Arlington, VA, 1996).

Table A-17. Number of first-university degrees by fields and as a percent of the 22-year-old population: 1994

Field	Japan		United States	
	Number of degrees	Percent of population	Number of degrees	Percent of population
Total..	461,898	23.3%	1,183,141	32.1%
Natural science......................	16,044	0.8	110,028	3.0
Agriculture.............................	13,361	0.7	12,947	0.4
Social science.......................	186,580	9.6	187,273	5.1
Engineering...........................	91,184	4.8	63,012	1.7
Other.....................................	154,729	7.9	809,881	4.2

NOTE: Differences in taxonomies: social science degrees in Japan combine economics, business administration, and marketing within economics; law is included within political sciences; computer science is included within engineering.

SOURCES: Government of Japan, Ministry of Education, Science and Culture, Basic Education Survey, 1993; and the National Science Foundation, SRS, *Science and Engineering Degrees 1966–94,* NSF 96-321 (NSF: Arlington, VA, 1996).

Table A-18. Undergraduate and graduate enrollments in science and engineering: 1975–94

Field	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	Japan									
	Undergraduate Enrollment									
Total	1,652,003	1,702,235	1,747,057	1,769,331	1,754,343	1,741,504	1,725,814	1,716,956	1,729,632	1,734,080
Total science & engineering	1,131,848	1,197,566	1,222,648	1,229,842	1,207,301	1,193,968	1,175,983	1,163,823	1,169,720	1,171,006
Natural sciences	37,495	38,455	39,704	40,781	40,484	40,381	40,701	40,702	42,047	42,560
Mathematics	12,731	13,088	13,301	13,743	14,094	14,198	14,332	14,486	15,550	15,886
Agricultural sciences	47,296	48,050	48,678	54,684	48,239	48,377	48,029	47,947	48,391	48,503
Social sciences	694,987	752,868	769,934	767,401	757,552	748,130	733,694	722,029	719,430	716,188
Engineering/comp. sci	339,339	345,105	351,031	353,233	346,932	342,882	339,227	338,659	344,302	347,869
Other	520,155	504,669	524,409	539,489	547,042	547,536	549,831	553,133	559,912	563,074
	Graduate Enrollment									
Total	48,464	51,856	53,251	53,267	53,244	53,992	55,603	58,642	62,000	65,692
Total science & engineering	32,198	34,907	35,791	35,084	34,061	33,853	34,084	36,117	38,294	40,452
Natural sciences	4,839	5,302	5,428	5,513	5,468	5,482	5,460	5,518	5,596	5,831
Mathematics	742	794	823	815	834	848	864	925	993	1,015
Agricultural sciences	3,699	4,077	4,064	3,878	3,786	3,641	3,712	4,588	5,529	5,834
Social sciences	6,882	6,882	6,924	6,926	7,025	6,480	6,249	6,335	6,490	6,681
Engineering/comp. sci	16,036	17,852	18,552	17,952	16,948	17,402	17,799	18,751	19,686	21,091
Other	16,266	16,949	17,460	18,183	19,183	20,139	21,519	22,525	23,706	25,240
	United States									
	Undergraduate Enrollment									
Total	7,449,816	7,362,827	7,488,772	7,478,376	7,599,805	7,826,514	7,915,285	7,913,659	7,989,679	7,939,920
Total science & engineering	NA	277,679	248,420	334,080	366,299	397,344	420,402	435,330	441,205	429,499
Natural sciences	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Math/comp. sciences	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Agricultural sciences	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Social sciences	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Engineering	NA	277,679	248,420	334,080	366,299	397,344	420,402	435,330	441,205	429,499
Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Graduate Enrollment									
Total	1,267,537	1,338,586	1,323,904	1,324,587	1,314,892	1,351,268	1,349,575	1,329,644	1,347,973	1,353,554
Total science & engineering	300,879	304,172	311,814	309,038	319,178	325,706	332,106	338,896	347,014	349,875
Natural sciences	85,176	87,597	101,224	101,051	100,878	101,040	100,612	101,755	102,968	103,547
Math/comp. sciences	25,333	25,719	25,160	25,936	26,736	28,912	32,339	36,990	40,713	42,985
Agricultural sciences										
Social sciences	122,010	124,085	116,750	118,290	119,851	121,465	119,621	116,485	112,236	110,647
Engineering	68,360	66,771	68,680	63,761	71,713	74,289	79,534	83,666	91,097	92,696
Other	966,658	1,034,414	1,012,090	1,015,549	995,714	1,025,562	1,017,469	990,748	1,000,959	1,003,679

See explanatory information and SOURCE at end of table.

Table A-18. Undergraduate and graduate enrollments in science and engineering: 1975–94

Field	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
	Japan									
	Undergraduate Enrollment									
Total	1,734,392	1,758,635	1,806,024	1,861,306	1,929,137	1,988,572	2,052,335	2,127,713	2,209,028	2,281,774
Total science & engineering	1,170,289	1,187,859	1,221,977	1,262,136	1,311,319	1,311,526	1,356,454	1,407,058	1,463,211	1,512,787
Natural sciences	43,700	44,088	45,314	45,828	46,856	48,581	50,075	52,587	55,312	57,578
Mathematics	15,978	16,218	15,762	16,104	17,141	18,197	19,298	20,513	21,424	22,441
Agricultural sciences	48,661	49,381	50,167	51,947	54,680	66,777	67,900	69,688	71,000	71,745
Social sciences	712,742	722,984	746,637	774,857	808,454	787,325	816,909	848,301	883,568	915,238
Engineering/comp. sci	349,208	355,188	364,097	373,400	384,188	390,646	402,272	415,969	431,907	445,785
Other	564,103	570,776	584,047	599,170	617,818	677,046	695,881	720,655	809,717	768,987
	Graduate Enrollment									
Total	69,688	74,272	78,914	82,476	85,263	90,238	98,650	109,108	122,360	138,752
Total science & engineering	42,940	45,921	49,435	51,950	53,517	57,325	62,899	70,864	80,239	91,181
Natural sciences	6,042	6,446	6,935	7,462	7,915	8,299	8,945	9,679	10,972	12,159
Mathematics	1,028	1,060	1,131	1,182	1,232	1,252	1,377	1,553	1,858	2,374
Agricultural sciences	5,989	6,256	6,790	6,238	5,403	6,040	5,958	7,366	8,431	9,432
Social sciences	6,810	7,119	7,521	7,901	8,331	9,020	10,054	11,238	12,589	14,676
Engineering/comp. sci	23,071	25,040	27,058	29,167	30,636	32,714	36,565	41,028	46,389	52,540
Other	26,748	28,351	29,479	30,526	31,746	32,913	35,751	38,244	42,121	47,571
	United States									
	Undergraduate Enrollment									
Total	7,956,065	8,069,364	8,185,221	8,361,683	8,549,853	8,725,465	8,936,087	8,997,921	8,738,936	8,727,334
Total science & engineering	420,864	407,657	392,198	385,412	378,277	380,287	379,977	382,525	375,944	367,298
Natural sciences	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Math/comp. sciences	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Agricultural sciences	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Social sciences	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Engineering	420,864	407,657	392,198	385,412	378,277	380,287	379,977	382,525	375,944	367,298
Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Graduate Enrollment									
Total	1,384,862	1,444,369	1,461,239	1,481,582	1,527,990	1,583,389	1,648,952	1,679,644	1,699,292	1,734,371
Total science & engineering	358,201	368,212	373,425	375,579	383,227	397,866	413,559	431,444	437,808	433,152
Natural sciences	104,070	105,541	104,974	105,580	107,348	109,472	112,643	116,879	119,769	121,087
Math/comp. sciences	47,341	49,316	50,575	51,323	51,766	54,165	54,668	56,700	56,511	53,609
Agricultural sciences	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Social sciences	110,808	111,499	113,939	115,732	120,069	126,607	132,606	139,748	144,666	144,591
Engineering	95,982	101,856	103,937	102,944	104,044	107,622	113,642	118,117	116,862	113,865
Other	1,026,661	1,076,157	1,087,814	1,106,003	1,144,763	1,185,523	1,235,393	1,248,200	1,261,484	1,301,219

KEY: NA = not available

NOTES: Natural sciences include physical, biological, earth, atmospheric, and oceanographic sciences. In U.S. undergraduate programs, only engineering students declare their major as they enter the university. At the graduate level, agricultural sciences are included in natural sciences.

SOURCES: NSF/SRS, *Selected Data on Graduate Students and Postdoctorates in Science and Engineering,* Fall 1994, NSF 95-316 (Arlington, VA, 1995); Engineering Workforce Commission, *American Association of Engineering Societies, Engineering and Technology Enrollments,* Fall 1979–94.

Table A-19. Masters degrees in science and engineering, by field: 1975–94

Field	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	Japan									
Total	13,505	13,349	14,900	15,723	15,846	15,258	15,320	15,855	16,733	18,493
Natural sciences 1/	1,150	1,284	1,366	1,396	1,445	1,441	1,434	1,510	1,581	1,642
Mathematics	232	188	228	229	221	208	231	206	232	268
Agricultural sciences	996	992	1,138	1,217	1,136	1,119	1,064	1,020	1,162	1,925
Social sciences	1,778	1,727	1,663	1,740	1,713	1,689	1,660	1,510	1,519	1,599
Engineering/comp. sci	6,149	5,882	7,034	7,764	7,693	7,214	7,036	7,427	7,776	8,377
Other	3,200	3,276	3,471	3,377	3,638	3,587	3,895	4,182	4,463	4,682
	United States									
Total	293,651	313,001	318,241	312,816	302,075	299,095	296,798	296,580	290,931	285,462
Natural sciences 1/	12,392	12,082	12,454	12,396	12,306	11,737	11,257	11,434	10,985	10,969
Math/comp. sci	6,637	6,466	6,496	6,421	6,101	6,515	6,787	7,666	8,160	8,939
Agricultural sciences	2,439	2,602	2,906	3,150	3,137	3,095	3,092	3,268	3,395	3,262
Social sciences	26,563	27,812	29,529	29,217	27,403	26,799	26,779	26,643	26,290	25,249
Engineering	15,167	16,045	16,012	16,080	15,279	15,943	16,451	17,557	18,886	20,145
Other	226,861	244,322	246,823	241,215	233,495	230,670	228,018	225,421	218,521	212,288

Field	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
	Japan									
Total	19,315	21,021	22,200	23,779	25,250	25,804	26,815	29,193	32,847	36,581
Natural sciences 1/	1,721	1,745	1,904	2,072	2,246	2,126	2,528	2,667	2,872	3,091
Mathematics	271	274	309	305	352	379	385	400	455	541
Agricultural sciences	2,078	2,172	2,159	2,300	2,505	1,606	1,596	1,763	2,072	2,297
Social sciences	1,715	1,740	1,831	1,947	2,115	2,291	2,473	2,866	3,250	3,510
Engineering/comp. sci	8,692	9,704	10,495	11,220	12,024	12,865	13,254	14,451	16,364	18,096
Other	4,838	5,386	5,502	5,935	6,008	6,537	6,579	7,046	7,834	9,046
	United States									
Total	287,213	289,829	290,532	300,091	311,050	324,947	338,498	354,207	370,973	389,008
Natural sciences 1/	10,859	10,935	10,624	10,438	10,648	10,294	10,082	10,195	10,202	10,957
Math/comp. sci	9,989	11,241	11,808	12,600	12,829	13,327	12,956	13,320	14,100	14,350
Agricultural sciences	3,113	2,975	2,776	2,746	2,570	2,634	2,600	3,037	3,272	3,410
Social sciences	25,629	25,584	25,325	25,145	26,635	27,538	28,717	29,537	31,187	33,977
Engineering	20,972	21,096	22,070	22,726	23,743	23,995	24,013	25,018	27,664	28,717
Other	212,128	213,717	213,381	221,924	230,269	243,351	260,130	273,100	284,548	297,597

1/ Natural sciences include physical, biological, earth, atmospheric, and oceanographic sciences.

NOTE: In Japanese data, computer science degrees are included in engineering.

SOURCES: Government of Japan, Ministry of Education, Science and Culture, Basic Education Survey, 1993; and the National Science Foundation, SRS, *Science and Engineering Degrees 1966–94,* NSF 96-321 (Arlington, VA, 1996).

Table A-20. Doctoral degrees in science and engineering, by field: 1975–94

Type and field	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
	Japan																			
	All earned doctoral degrees—university-based and ronbun "thesis" doctorates																			
Total	4,592	5,138	5,322	5,648	5,812	6,269	6,599	6,810	7,233	7,477	7,978	8,533	9,157	9,602	10,036	10,633	10,885	11,576	10,919	11,367
Natural sciences 1/	676	717	843	782	814	822	791	762	774	807	860	820	837	881	876	835	892	1,009	934	1,081
Mathematics																				
Agricultural sciences	381	490	518	442	430	527	529	521	515	614	697	646	715	746	734	719	870	824	816	952
Social sciences	84	85	88	88	76	76	76	93	97	90	127	136	149	167	177	183	200	243	249	278
Engineering/comp. sci. 2/	986	1,079	1,043	1,166	1,195	1,186	1,236	1,309	1,290	1,291	1,404	1,493	1,547	1,717	1,774	1,967	2,094	2,362	2,278	2,501
Other	2,465	2,767	2,830	3,170	3,297	3,658	3,967	4,125	4,557	4,675	4,890	5,438	5,909	6,091	6,475	6,929	6,829	7,138	6,458	6,555
	University based doctoral degrees																			
Total	1,658	1,814	1,859	1,974	2,154	2,290	2,424	2,318	2,401	2,725	3,004	3,252	3,608	3,949	4,349	4,548	4,779	5,134	4,477	4,925
Natural sciences 1/	354	388	441	425	469	457	433	395	397	459	497	479	464	518	531	522	586	638	563	710
Mathematics																				
Agricultural sciences	135	160	187	181	165	193	191	191	192	193	237	198	274	322	304	337	385	376	368	504
Social sciences	29	24	24	25	22	20	27	34	25	27	34	37	41	42	52	73	67	90	96	125
Engineering/comp. sci. 2/	459	490	455	523	545	523	541	563	489	447	480	505	621	788	792	882	983	1,184	1,100	1,323
Other	681	752	752	820	953	1,097	1,232	1,139	1,298	1,599	1,756	2,033	2,208	2,279	2,670	2,734	2,758	2,846	2,166	2,263
	Ronbun "thesis" doctoral degrees																			
Total	2,934	3,324	3,463	3,674	3,658	3,979	4,175	4,492	4,832	4,752	4,974	5,281	5,549	5,653	5,687	6,085	6,106	6,442	6,442	6,442
Natural sciences 1/	322	329	402	357	345	365	358	367	377	348	363	341	373	363	345	313	306	371	371	371
Mathematics																				
Agricultural sciences	246	330	331	261	265	334	338	330	323	421	460	448	441	424	430	382	485	448	448	448
Social sciences	55	61	64	63	54	56	49	59	72	63	93	99	108	125	125	110	133	153	153	153
Engineering/comp. sci. 2/	527	589	588	643	650	663	695	746	801	844	924	988	926	929	982	1,085	1,111	1,178	1,178	1,178
Other	1,784	2,015	2,078	2,350	2,344	2,561	2,735	2,986	3,259	3,076	3,134	3,405	3,701	3,812	3,805	4,195	4,071	4,292	4,292	4,292
	United States																			
Total	32,952	32,946	31,716	30,875	31,239	31,020	31,356	31,111	31,282	31,337	31,298	31,899	32,367	33,499	34,324	36,068	37,517	38,853	39,754	41,011
Natural sciences 1/	8,103	7,863	7,676	7,601	7,817	7,864	7,995	8,195	8,195	8,336	7,326	7,486	7,679	8,157	8,099	8,589	9,086	9,372	9,562	9,996
Math/comp. sci. 2/	1,147	1,003	964	959	979	962	960	940	987	993	998	1,128	1,190	1,264	1,471	1,597	1,839	1,927	2,024	2,022
Agricultural sciences	905	788	782	853	855	912	982	951	1,015	997	1,111	998	977	1,015	1,086	1,176	1,074	1,063	969	1,078
Social sciences	6,538	6,768	6,720	6,668	6,582	6,470	6,774	6,494	6,672	6,506	6,335	6,450	6,337	6,310	6,532	6,614	6,806	6,873	7,190	7,289
Engineering	3,011	2,838	2,648	2,425	2,494	2,479	2,528	2,646	2,781	2,913	3,166	3,376	3,712	4,187	4,543	4,894	5,215	5,439	5,696	5,822
Other	13,248	13,686	12,926	12,369	12,512	12,333	12,117	11,885	11,632	11,592	12,362	12,461	12,472	12,566	12,593	13,198	13,497	14,179	14,313	14,800

1/ Natural sciences include physical, biological, earth, atmospheric, and oceanographic sciences.

2/ In Japanese higher education data, computer science is included in engineering.

NOTE: Data for total and Ronbun "thesis" doctorates are estimated for 1993–94. Data for university-based doctoral degrees are taken from the Monbusho published survey of education.

SOURCES: Government of Japan, Ministry of Education, Science and Culture, unpublished tabulations, 1996; and National Science Foundation, Science Resources Studies Division, *Selected Data on Science and Engineering Doctorate Awards: 1995* , NSF 96-303 (NSF: Arlington, VA, 1996).

Table A-21. Doctoral degrees by field as a percent of the 29-year-old population: 1994

Field	Japan		United States	
	[Number]	[Percent]	[Number]	[Percent]
Total………………………………...................................	11,563	0.66%	41,011	1.08%
Natural sciences & engineering total......................	4,534	0.26	18,922	0.50
Natural sciences...	1,081	0.06	12,018	0.32
Agricultural sciences…………................................	952	0.05	1,078	0.03
Social sciences………………................................	278	0.02	7,289	0.19
Engineering……………….....................................	2,501	0.14	5,826	0.15
Other……………………...	6,751	0.39	14,800	0.39

SOURCES: Government of Japan, Monbusho, Annual Survey of Education; for United States, National Science Foundation, Science Resources Studies Division, *Selected Data on Science and Engineering Doctorate Awards: 1995,* NSF 96-303 (NSF: Arlington, VA, 1996).

Table A-22. Distribution of higher education R&D expenditures, by field: 1993

Field	Japan	United States
	[Percent]	
Total	100.0%	100.0%
Natural sciences	9.4	35.0
Math/computer sciences 1/	N/A	3.0
Agricultural	4.3	7.8
Social sciences	24.0	6.2
Engineering	22.4	15.8
Medical	25.0	26.5
Other	14.9	5.5

1/ In Japanese data, mathematics is included in natural sciences, computer science in engineering.

KEY: NA = not available

NOTES: In Japan, R&D expenditures include faculty salaries; all university and junior college teachers are regarded as researchers. The high proportion of resources in the social sciences reflects the inclusion of the salaries of large numbers of social science faculty. Natural sciences include physical, biological, earth, atmospheric, and oceanographic sciences. Social sciences include psychology.

SOURCES: Government of Japan, Management and Coordination Agency, Report on the Survey of Research and Development, 1995; and National Science Foundation, *Academic Science and Engineering R&D Expenditures, 1993,* NSF 95-332 (Arlington, VA, 1995).

Table A-23. Scientific and technical articles, by field: 1981–93

Field	1981	1983	1985	1987	1989	1991	1993
	Article publication year						
	Japan						
	[Number]						
All fields	25,086	26,368	29,617	28,894	32,832	34,375	36,674
Clinical medicine	5,908	6,730	7,861	8,408	9,559	10,269	11,163
Biomedical research	3,429	3,776	4,339	4,556	5,175	5,442	5,803
Biology	2,404	2,371	2,456	2,267	2,363	2,557	2,543
Chemistry	5,926	5,571	5,887	5,744	5,907	6,173	6,117
Physics	3,750	3,750	4,775	4,557	6,116	6,088	6,982
Earth and space sciences	394	381	592	644	736	725	797
Engineering and technology	2,827	3,290	3,213	2,460	2,580	2,777	2,976
Mathematics	449	498	495	258	395	343	293
	United States						
	[Number]						
All fields	132,279	132,415	137,771	134,497	140,833	142,333	140,588
Clinical medicine	48,072	48,055	50,595	49,904	50,510	50,142	50,258
Biomedical research	21,847	22,496	24,461	24,542	26,541	26,918	27,120
Biology	14,740	14,216	13,083	12,231	12,726	12,862	11,304
Chemistry	10,880	11,010	11,585	11,827	12,405	13,086	13,252
Physics	13,053	13,021	15,903	16,078	17,649	18,077	16,912
Earth and space sciences	7,257	6,862	7,663	7,797	7,770	8,138	8,522
Engineering and technology	12,486	13,105	10,822	9,225	9,568	9,999	10,051
Mathematics	3,943	3,648	3,659	2,893	3,664	3,111	3,170

See explanatory information and SOURCE at end of table.

Field	Article publication year						
	1981	1983	1985	1987	1989	1991	1993
	Japan						
	[Percent]						
All fields	6.8%	7.1%	7.6%	7.6%	8.1%	8.5%	8.8%
Clinical medicine	5.1	5.6	6.3	6.7	7.3	7.9	8.5
Biomedical research	6.2	6.6	6.7	7.1	7.5	7.9	8.4
Biology	6.1	6.3	7.0	6.9	6.9	7.5	7.6
Chemistry	10.9	10.3	10.7	10.8	10.5	10.9	10.5
Physics	8.2	8.0	8.8	8.5	10.0	10.0	10.9
Earth and space sciences	2.3	2.3	3.3	3.5	3.9	3.7	3.8
Engineering and technology	9.2	10.3	11.5	10.1	10.1	10.1	10.3
Mathematics	4.3	5.3	5.2	3.6	4.3	4.6	3.6
	United States						
	[Percent]						
All fields	35.9	35.4	35.3	35.6	34.9	35.1	33.6
Clinical medicine	41.3	40.3	40.3	39.9	38.8	38.5	38.4
Biomedical research	39.5	39.3	37.8	38.2	38.7	38.9	39.4
Biology	37.6	37.6	37.5	37.3	37.2	37.6	33.7
Chemistry	20.0	20.3	21.0	22.2	22.1	23.1	22.8
Physics	28.6	27.8	29.4	30.1	28.7	29.8	26.5
Earth and space sciences	42.7	41.6	43.0	42.6	41.5	41.7	40.6
Engineering and technology	40.7	40.9	38.6	37.9	37.6	36.2	34.6
Mathematics	38.2	38.5	38.3	40.7	39.9	42.1	38.9

SOURCES:

special tabulation, 1995.

Table A-24. U.S. patents granted to Japanese and U.S. inventors: 1980–93

Year	Japan	United States
	[Number]	
1980	7,124	37,356
1981	8,388	39,223
1982	8,149	33,896
1983	8,793	32,871
1984	11,110	38,367
1985	12,746	39,555
1986	13,209	38,126
1987	16,557	43,518
1988	16,158	40,496
1989	20,168	50,185
1990	19,524	47,393
1991	21,027	51,183
1992	21,925	52,253
1993	22,292	53,236

SOURCE: National Science Board, *Science and Engineering Indicators, 1996* , NSB 96-21, (Washington, D.C.: Government Printing Office, 1996).

Table A-25. Output per worker-hour in manufacturing: 1977–94

Year	Japan	United States
	[Index 1982 = 100]	
1977	77.1	96.2
1978	81.3	96.3
1979	87.7	94.9
1980	91.1	92.9
1981	95.0	96.2
1982	100.0	100.0
1983	102.5	102.2
1984	107.9	103.5
1985	114.9	106.7
1986	113.0	109.5
1987	122.4	116.6
1988	129.6	119.2
1989	138.7	119.9
1990	149.1	122.1
1991	156.9	124.9
1992	156.6	127.5
1993	159.5	132.0
1994	164.2	137.4

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, September 1995.

Table A-26. Value of internationally traded technological know-how receipts and payments: 1990–93 1/

Receipts and payments	Japan			
	1990	1993	1990	1993
	[Billions of current yen]		[Millions of current dollars 2/]	
Receipts	¥373.90	¥450.20	$3,362.00	$4,049.00
Payments	869.40	814.70	7,818.00	7,326.00
Balance	(495.50)	(364.50)	(4,456.00)	(3,277.00)
Ratio of receipts to payments	0.43	0.55	0.43	0.55
	United States			
			[Millions of current dollars 2/]	
Receipts	...	...	2,333.00	2,755.00
Payments	...	...	665.00	1,036.00
Balance	...	...	(1,668.00)	(1,719.00)
Ratio of receipts to payments	...	...	3.51	2.66

1/ Technological know-how includes industrial processes, patents, and other proprietary inventions and technologies.

2/ IMF rate yen to a dollar, 1990: ¥144.8; 1993: ¥111.20.

SOURCES: Government of Japan, *Indicators of Science and Technology* (1996); National Science Foundation, Science Resources Studies Division, *Science and Engineering Indicators, 1996* , NSB 96-21, Arlington, VA.

Table A-27. Japanese manufacturing trade in technical know-how by selected industries: 1990 and 1993

Industry	1990			1993		
	Payments	Receipts	Receipts/payments	Payments	Receipts	Receipts/payments
	[Millions of current yen]					
All manufacturing, total	¥32,6901	¥3,16241	0.97	¥35,9601	¥39,4144	1.10
Food	8,471	8,337	0.98	8,430	5,432	0.64
Textiles	4,847	4,648	0.96	6,188	4,854	0.78
Chemicals and allied products	56,866	53,616	0.94	61,368	59,348	0.97
Industrial chemicals	23,242	29,451	1.27	18,658	22,201	1.19
Drugs and medicines	21,483	813	0.04	34,591	31,020	0.90
Petroleum and coal	3,752	487	0.13	3,077	237	0.08
Rubber	3,787	4,804	1.27	4,114	5,285	1.28
Ceramics	4,092	9,025	2.21	3,828	9,808	2.56
Iron and steel	4,776	21,572	4.52	3,403	13,294	3.91
Non-ferrous metals	10,702	7,054	0.66	3,620	3,640	1.01
Fabricated metals	2,279	2,004	0.88	1,505	4,698	3.12
General machinery	32,986	13,210	0.40	25,554	18,425	0.72
Electrical machinery	120,553	86,708	0.72	159,159	127,377	0.80
Electrical equipment	28,517	28,164	0.99	24,431	8,288	0.34
Communications and electronic equipment	92,036	58,544	0.64	134,729	10,975	0.08
Motor vehicles	7,248	83,042	11.46	8,748	124,249	14.20
Professional and scientific instruments	8,302	12,556	1.51	22,747	640	0.03

SOURCE: Government of Japan, Management and Coordination Agency, *Report on the Survey of R&D,* Tokyo, 1995.

Table A-28. Japanese trade balance with the United States in advanced technology products: 1990–94 1/

Year	Balance	Exports to U.S.	Imports from U.S.	Balance	Exports to U.S.	Imports from U.S.
	[Millions of current dollars]			[Millions of current dollars]		
	All technologies			Computer Integrated Manufacturing		
1990	$7,233.1	$19,450.2	$12,217.1	$510.4	$1,103.5	$593.1
1991	7,434.2	19,799.5	12,365.3	585.7	1,247.1	661.4
1992	8,854.7	21,458.4	12,603.7	628.3	1,106.5	478.2
1993	12,789.4	24,936.1	12,146.7	959.3	1,504.2	544.9
1994	14,317.5	28,732.2	14,414.7	1,144.1	1,963.1	819.0
	Biotechnologies			Material Design		
1990	(177.1)	1.4	178.5	44.9	482.0	437.1
1991	(174.7)	1.9	176.6	(36.5)	461.8	498.3
1992	(152.2)	1.6	153.8	65.3	195.3	130.0
1993	(138.1)	1.3	139.4	51.2	240.7	189.5
1994	(187.9)	1.0	188.9	128.4	337.5	209.1
	Life Sciences			Aerospace		
1990	56.5	746.6	690.1	(3,593.0)	487.3	4080.3
1991	162.4	889.6	727.2	(3,135.9)	614.5	3750.4
1992	185.4	910.4	725.0	(3,791.6)	575.3	4366.9
1993	50.4	891.5	841.1	(2,980.9)	501.9	3482.9
1994	(111.0)	895.9	1,006.9	(3,329.1)	555.8	3884.9
	Opto-electronics			Weapons		
1990	688.2	798.3	110.1	(89.3)	2.2	91.5
1991	1,461.8	1,603.1	141.3	(98.0)	2.6	100.6
1992	1,882.5	1,939.5	57.0	(84.5)	2.6	87.1
1993	1,746.4	1,823.7	77.3	(106.4)	3.4	109.8
1994	1,291.1	1,454.0	162.9	(96.6)	4.9	101.5
	Computers and Telecommunications			Nuclear Technology		
1990	8,703.6	13,078.2	4,374.6	(726.4)	1.8	728.2
1991	7,239.2	11,611.7	4,372.5	(812.6)	1.4	814
1992	8,168.7	12,444.4	4,275.7	(811.4)	2.2	813.6
1993	10,197.6	14,319.4	4,121.8	(823.5)	4.4	827.9
1994	11,343.0	16,146.9	4,803.9	(851.8)	2.4	854.2
	Electronics			Software		
1990	1,815.5	2,749.0	933.5	(119.9)	22.2	142.1
1991	2,242.8	3,365.7	1,122.9	(139.1)	31.3	170.4
1992	2,764.3	4,280.7	1,516.4	(149.4)	28.7	178.1
1993	3,833.6	5,645.5	1,811.9	(179.3)	25.6	204.9
1994	4,987.3	7,370.7	2,383.4	(235.0)	26.0	261

1/ The list of advanced technology products is compiled by the U.S. Bureau of the Census. To be included in one of the categories, a product must contain a significant amount of one of the leading-edge technologies, and the technology must account for a significant portion of the product's value.

NOTE: Data reported on Japanese exports to the United States are actually U.S. imports from Japan as reported by the Bureau of the Census. Likewise, Japanese imports are U.S. exports to Japan as reported in the Census data.

SOURCE: U.S. Department of Commerce, Bureau of the Census, Foreign Trade Division.